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EXPERIMENTAL TEST PLAN FOR THE EVALUATION OF AIRCRAFT SEPARATION ASSURANCE DISPLAYS USING AIRLINE FLIGHT SIMULATORS

Prepared for
Department of Transportation
Federal Aviation Administration
Washington, D.C.

June 1978

Publication Number 1343-01-1-1753

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This test plan describes an experiment for evaluating the cockpit impact of the use of Aircraft Separation Assurance information using a jet transport aircraft simulator and operational airline flight crews. Three concepts for displaying ASA information will be utilized during the evaluation; six flight scenarios, each with a set of six flight conflicts, will be used. Figures of merit for evaluating the display concepts include response delay times, achieved miss distances, deviation from desired flight, path, achieved acceleration rates, and qualitative crew opinions.

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FOR THE EVALUATION OF
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USING AIRLINE FLIGHT SIMULATORS

June 1978

Prepared for

Department of Transportation
Federal Aviation Agency
Washington, D.C. 20591

under Contract DOT-FA78WA-4091

by

Thomas Berry

ARINC Research Corporation
a *Subsidiary of Aeronautical Radio, Inc.*
2551 Riva Road
Annapolis, Maryland 21401

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FOREWORD

This Experimental Test Plan is submitted in accordance with the provisions of Contract DOT-FA78WA-4091. While it is a complete and practical plan for achieving the experimental objectives of the contract, it does not represent the only approach to meeting these objectives. It will be reviewed and commented on by a number of organizations and individuals. Because much of the experiment is software-controlled, it is possible to incorporate comments and changes into the experiment following preparation of the plan. The reader is invited to submit comments either directly to FAA, ARD-250, or to the author at ARINC Research Corporation.

ABSTRACT

This test plan describes an experiment for evaluating the cockpit impact of the use of Aircraft Separation Assurance information using a jet transport aircraft simulator and operational airline flight crews. Three concepts for displaying ASA information will be utilized during the evaluation; six flight scenarios, each with a set of six flight conflicts, will be used. Figures of merit for evaluating the display concepts include response delay times, achieved miss distances, deviation from desired flight path, achieved acceleration rates, and qualitative crew opinions.

CONTENTS

CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

The Systems Research and Development Service of the Federal Aviation Administration is conducting a program to develop an Aircraft Separation Assurance (ASA) System for use within the National Airspace System. The program includes examination of methods for detecting potential aircraft conflicts, resolution of such conflicts, and cockpit display of the resolution. Work is progressing in all three program phases. This test plan describes an experiment that will be performed to evaluate various types of cockpit displays of ASA information in a realistic airline operational environment.

This experiment involves the simulation of a jet transport aircraft equipped with an Aircraft Separation Assurance System operating in the near-term traffic projected for a major air transportation hub. The overall objective of this simulation is to investigate the interaction between the flight crew and the air traffic environment when the crew is provided one of three types of ASA displays. Specific test objectives are presented in Chapter Two.

Previous simulations of ASA displays have concentrated on light aircraft operated by one pilot in a one-on-one encounter (see NAFEC technical letter report NA-77-73-LR). This ASA simulation is unique in that it utilizes a jet transport cockpit simulator operated by qualified flight crews in a realistic air traffic environment.

The ASA display devices to be evaluated cover a range of techniques and capabilities. One device, the Instantaneous Vertical Speed Indicator (IVSI), has been used in the previous air carrier and general aviation simulations and can provide the basis for comparing the reaction between the airline crews participating in these tests and the results of prior tests. The other displays represent new technology or new application of existing technology to a cockpit display.

ARINC Research Corporation is conducting this simulation under Contract DOT-FA78WA-4091 and is responsible for the following:

1. Selecting the displays to be evaluated
2. Selecting an appropriate simulation facility for conducting the experiment

3. Designing test scenarios
4. Preparing a Simulation Test Plan
5. Developing a Simulation Test Bed
6. Conducting the simulation test
7. Analyzing collected data
8. Reporting results
9. Preparing for flight test of selected ASA systems

Items 1 through 3 have been completed and are summarized in this test plan, which represents item 4. Items 5 and 6 will be completed prior to March 1979. The remainder of the items will be completed prior to December 1979.

ARINC Research Corporation has subcontracted with United Airlines to provide a flight simulator, test crews, and maintenance support for the simulation.

The test plan describes a program for evaluating three ASA display devices using professional airline crews in a United Airlines flight simulator. Six scenarios, each representing all phases of an airline flight, will be used in the evaluation. Six encounters with other aircraft are included in each scenario. A total of 18 scenario/display combinations are used. Thirty airline crews -- 15 United Airlines flight crews and 15 volunteer crews from other airlines -- will participate in the experiment.

This test plan is organized into seven chapters and three appendixes. Chapter Two presents the objectives and scope of the experiment. Chapter Three describes the test bed that will be used in the experiment. The displays that will be used and the simulation software are discussed in Chapters Four and Five, respectively.

Chapter Six describes the experimental procedure to be used, and Chapter Seven presents the data collection and analysis plan.

The appendixes present flight scenarios (Appendix A), the flight crew procedures manual ASA revision (Appendix B), and the flight crew debriefing forms (Appendix C).

CHAPTER TWO

OBJECTIVES AND SCOPE OF THE EXPERIMENT

2.1 OBJECTIVES

The primary objective of the experiment is to evaluate the operational impact of the introduction of Aircraft Separation Assurance (ASA) Systems in commercial air carrier aircraft. A significant secondary objective is to expose a number of air carrier pilots to the concept of automatic separation assurance by their participation in this experiment and to obtain their opinions regarding the ASA displays, the expected escape maneuvers, and the ASA concept as currently defined.

The candidate ASA display devices to be evaluated include three distinct display types: (1) an electromechanical device that displays ASA commands and messages using lighted display segments, (2) an alphanumeric device that can display a 40-character message, and (3) a cathode ray tube (CRT) device that displays both alphanumerics and symbols. All devices are displays only; there is no capability for crew input. These candidate displays represent selections from a larger field of candidates that has been progressively narrowed and redefined as a result of previous related experiments; they were selected in coordination with representatives of the Air Transport Association and Air Line Pilots Association. With the potential for a catastrophic collision increasing with the growing numbers of commercial aircraft and the higher average number of passengers carried aboard them, the knowledge to be gained in this experiment is of major importance to the continued safety of air transportation.

2.2 SCOPE

The experiment is designed to measure the responses of professional airline crews to specific potential collision/conflict situations when they are flying an aircraft equipped with a system that is designed to provide warnings and commands early enough that the crew can maneuver to avoid an actual collision. The experiment will attempt to determine which of three types of system displays elicit the best crew response under a number of variable conditions, including:

- Phase of flight
- Relative aircraft position

- Visual sighting of other aircraft
- Amount of information displayed
- Rate at which information is generated

In addition to measuring crew reaction to conflict situations that explore the impact of the variables, the experiment is designed to collect comments and opinions based on the experience of these career airline pilots.

Two methods will be used to collect data. A simulation test bed will be established by which responses to aircraft conflict situations by professional airline flight crews will be measured. This test bed, described in Chapter Three, consists of a high-fidelity aircraft cockpit simulator equipped with a computer-generated scene system that is interconnected with an appropriate experimental control and data collection system. A set of scenarios and conflict situations, as described in Appendix A, will be used to create the realistic crew reactions desired. Three types of displays, as described in Chapter Four, will be comparatively evaluated by using the simulation test bed.

In addition to collection of the crew responses measured in the simulation test bed, debriefing questionnaires will be used to gather subjective evaluations of the displays and the procedures used during the simulation exercises. The questionnaires will provide an opportunity for participants to present their evaluation of the operational requirement for an ASA system.

Previous airline pilot opinion on the ASA concept and displays has been presented voluntarily by a limited number of individuals who regularly fly as crew members. This is the first time a relatively large number of professional line-qualified crews have evaluated ASA display devices in standard-configuration air carrier operations. Their opinions and comments relating to operational utility of ASA displays and procedures should be extremely valuable to the development community.

CHAPTER THREE

SIMULATION TEST BED

The simulation test bed, diagrammed in Figure 3-1, is an interactive, distributed processing system that includes three computers, the simulator cockpit, a computer-generated scene, ASA display devices, input/output devices, and data storage devices. It is designed to permit evaluation of flight crew reactions to aircraft conflict and near-conflict situations that could present a significant element of danger if conducted in actual aircraft. The use of a simulator makes experimental problem control and data collection much simpler than would be possible in an experiment using actual aircraft. In addition, simulation presents significant cost and time advantages over an experiment that might require several transport aircraft operating in controlled airspace under the precise conditions necessary for experimental work.

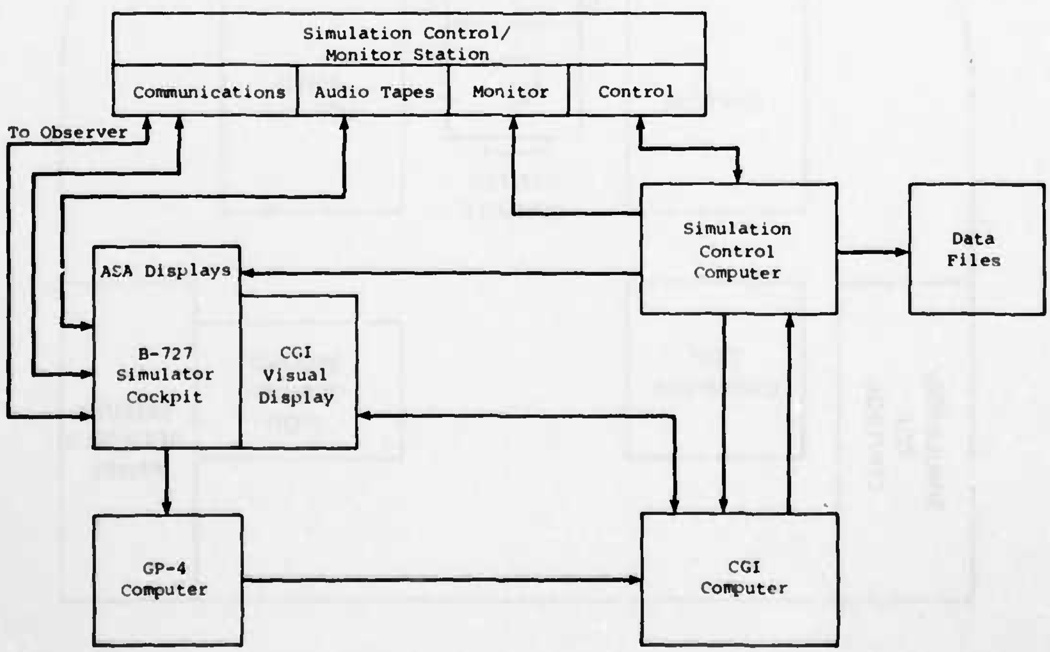

Figure 3-1. SIMULATION TEST BED

3.1 AIRCRAFT SIMULATOR

The aircraft simulator selected for this experiment represents the Boeing 727 aircraft, one of the most widely used commercial jet transports. The B-727 is expected to remain in the fleets of most major airlines for the next 20 years; therefore, its performance and handling characteristics make it most appropriate for use in evaluating ASA displays.

The simulator is located in the United Airlines Flight Training Center at Stapleton International Airport, Denver, Colorado. Its cockpit replicates a United Airlines B-727-200 aircraft in the United Airlines fleet. The cockpit module layout is shown in Figure 3-2.

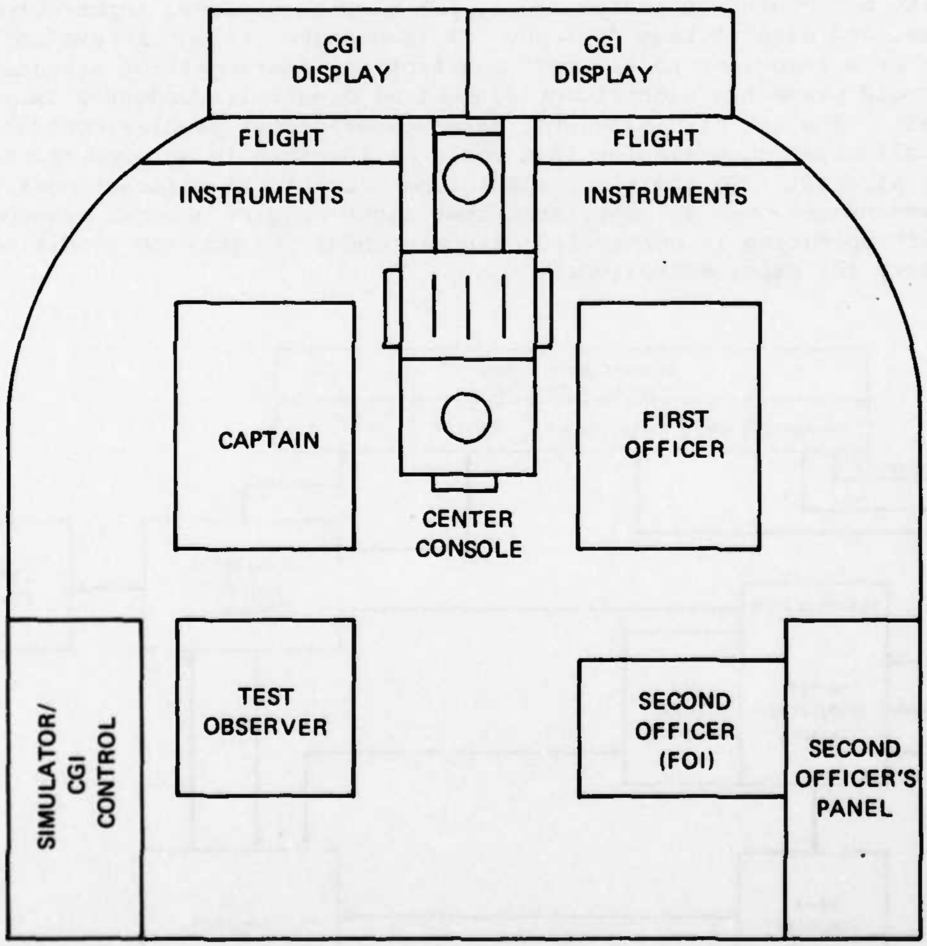

Figure 3-2. SIMULATOR LAYOUT

Figures 3-3 and 3-4 show the captain's and second officer's instrument panels, respectively. Figure 3-5 presents a detail of the center console forward of the throttle quadrant and aft of the instrument panel.

The cockpit module is mounted on a 3-degrees-of-freedom motion base that simulates the movement of an aircraft cockpit. The motion base and the aircraft instruments are controlled by a GP-4 computer, which is supplied as part of the Singer-Link-developed simulator and is located in a room adjacent to the cockpit module. Simulator control is effected through a control panel located inside the cockpit module at the second officer's station. This panel is operated by the flight operations instructor, who also serves as the second officer during regular training.

The normal mission of the simulator is recurrent and upgrade training of United Airlines flight crews and flight crews of other airlines, Government agencies, and private operators undergoing training at the center. The simulator is designed to allow the flight operations instructor to introduce adverse weather, turbulence, and system-malfunction problems to the crew undergoing training. It can create catastrophic conditions in an extremely realistic manner.

The simulator incorporates a visual display in the forward windows of the cockpit -- a full-color representation of a night landscape of a large metropolitan area, including a major airport. The landscape scene, composed of more than 9,000 lights, is created from a data base stored in the CGI computer located with the simulator GP-4 computer. The data base is stored as a file of 3-dimensional coordinates within a selected area. Each light in the display is also identified as to color and intensity. Proper programming allows simulation of any selected area.

The CGI computer and GP-4 computer both operate from the same coordinate reference point. The GP-4 computer simulates navigation stations within the coordinate system, and the CGI computer represents lights within the coordinate system. As the cockpit simulator moves through the coordinate system, its position in relation to the navigation stations is displayed on the cockpit instrumentation. The simulator position within the coordinate system is transferred from the GP-4 computer to the CGI computer, which causes the visual display to realistically display the relationship between the simulator cockpit and the ground lights.

3.2 COMPUTER-GENERATED IMAGE (CGI) SYSTEM

A computer-generated scene, depicting a nighttime view from the forward windshield of a jet transport aircraft, is created to add realism to the regular flight training conducted in the simulator. For purposes of this experiment, the visual scene will display moving lights that represent aircraft flying in the area normally in view of the crew. As many as six aircraft can be presented within the view of the crew at any time. These aircraft are represented by flashing red lights, flashing white lights, or a combination of steady green, red, and white lights with a flashing red

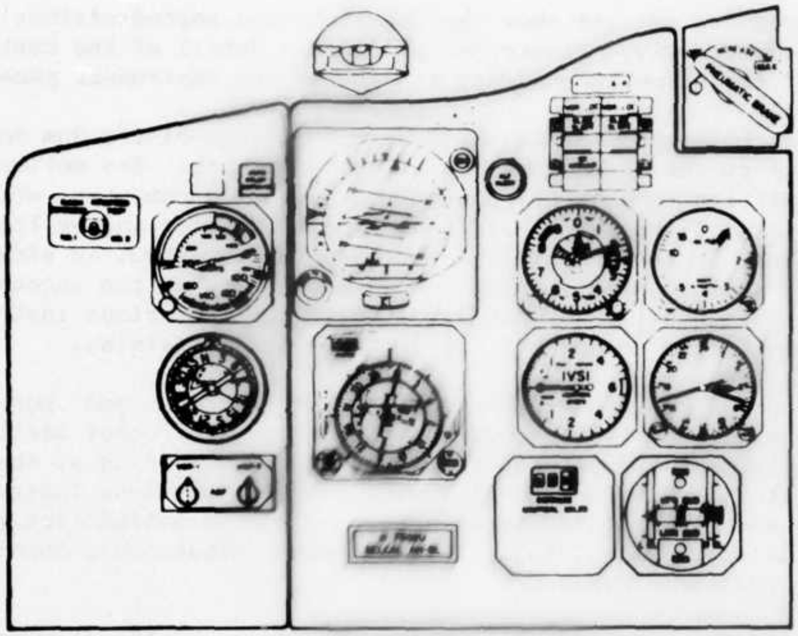

Figure 3-3. CAPTAIN'S PANEL FOR B-727-200

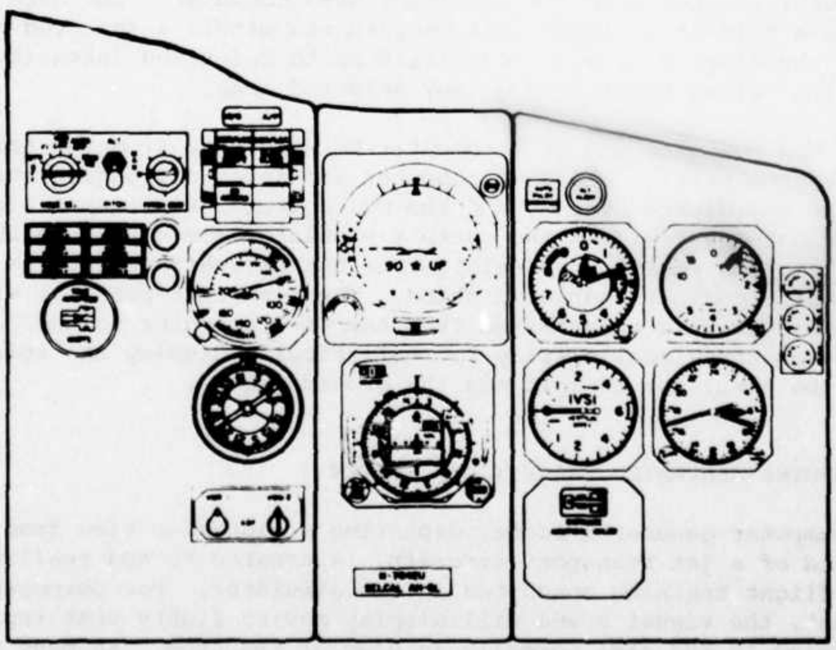

Figure 3-4. FIRST OFFICER'S PANEL FOR B-727-200

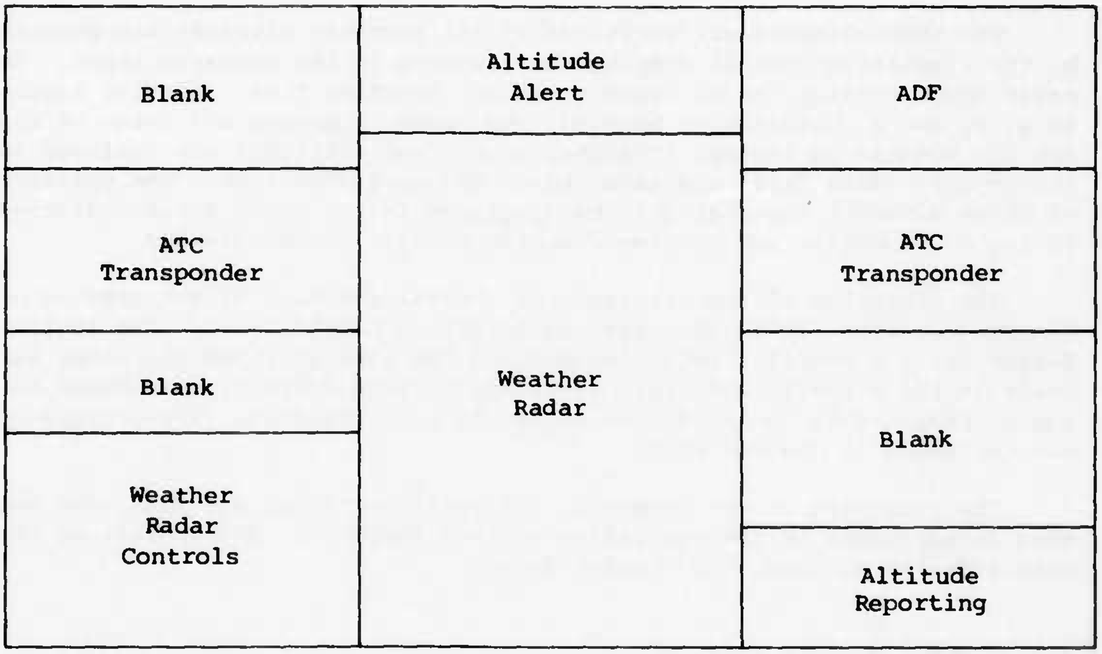

Figure 3-5. B-727 FORWARD PEDESTAL

light. Only one such multi-light aircraft can be displayed at any given time, and it will represent close-in aircraft.

The position of the displayed lights in relation to the simulator cockpit is controlled by the CGI computer in a manner quite similar to that used to control fixed, ground lights. The computer examines its light data base cyclically to determine the location, color, and intensity of all lights in the data base. This information is used to turn on or off the lights that fall within the cockpit simulator's front window viewing area. For purposes of this simulation, a program module has been prepared by which the light data base is accessed and updated by the simulation control computer to provide real-time location updates of aircraft flying through the scenario area.

3.3 SIMULATION CONTROL COMPUTER

The simulation control computer is used for four major functions:

- Generation of aircraft positions
- Operation of ASA logic
- Driving of ASA Displays
- Management of data collection files

The three-dimensional positions of all scenario aircraft are generated by the simulation control computer in response to the scenario input. Scenario input consists of an identification; starting time; starting location in x, y, and z coordinates; heading; and speed. Changes and rates of change for the dynamic parameters (heading, speed, and altitude) are included in the scenario data files and executed at the specified time. The positions of those aircraft designated to be displayed in the scene are transferred to the CGI computer and displayed on the cockpit visual display.

The operation of the ASA logic is a vital function of the simulation control computer (it is discussed in detail in Chapter Six). The logic determines the conflict potential between the simulator and all other aircraft in the scenario and presents an appropriate advisory or command to the display device installed and active in the simulator. These displays are discussed in Chapter Five.

The recording of the commands, aircraft positions, and simulator movement is performed by the simulation control computer. The content of the data files is discussed in Chapter Seven.

3.4 CONTROL/MONITOR STATION

The control/monitor station is used by the simulation controller to build or modify the scenario files, initiate the desired conflicts and background traffic, monitor the progress of the simulation, and control the operation of the data collection devices. The control/monitor station is made up of three input/output devices:

- Console terminal for interactive simulation control
- Video terminal to display information of transitory interest
- Storage tube graphic display terminal to display a history of the simulator and aircraft tracks during conduct of the simulation

The simulation controller tracks the progress of the flight by monitoring the storage tube display to determine x-y position of all tracks and the video terminal to determine aircraft altitude. The video terminal also presents the advisories and commands currently being displayed on the ASA devices in the simulator.

3.5 AUDIO SYSTEM

The simulation controller has access to the simulator audio system for controlling the operation of traffic tapes that simulate ATC/aircraft communications to provide a realistic background. In addition, he has a private communications link with the test observer inside the simulator. Examples of the types of communications are discussed in Chapter Six.

3.6 DATA FILES

The data files will be used to collect data generated during the experiment for later analysis. This section describes the techniques of storing the data; the content of the data files is discussed in Chapter Seven.

The simulation test bed has three methods of preserving data generated during the simulation:

- Magnetic cartridge disk
- Nine-track industry-compatible magnetic tape
- Hard copy printout on a medium-speed printer

The major portion of the data collected during the simulation will be stored on magnetic disks, each of which has a capacity for storing 1.2 million words of data. The nine-track tape will be used for more permanent storage and for transporting data between the simulation test bed and other computers that may be used for data reduction. The medium-speed printer provides a capability to reproduce summaries, analyses, and other data generated by the simulation.

Assignment of the data recording devices is under the control of the simulation controller.

CHAPTER FOUR

DISPLAYS

The displays selected for use during the simulation represent three distinct methods for presenting ASA information to flight crews. All selected displays can be used with either an air-derived or ground-derived ASA system (or equally well with a combination system). The displays represent a good engineering design; however, optimization of the displays is outside the scope of the current simulation. It is fully expected that comments received from the test crews will provide some insight into features that should be included in any optimized display.

The following test displays, representing a range of alternative display types that can be used in existing aircraft, have been selected for use in this experiment in coordination with aircraft operators and users:

- Modified Instantaneous Vertical Speed Indicator (IVSI)
- Light Emitting Diode (LED)
- Cathode Ray Tube (CRT)

All displays are driven by the simulation control computer as described in Chapter Three and illustrated in Figure 4-1. The simulation control computer tracks the position of the simulator and all scenario aircraft, applies the ASA detection and resolution logic, derives the appropriate advisory or warning message, formats the message for the display under test, and transmits it to the cockpit display. There will be an audio alert, common to all displays, that will sound when a positive ASA command is first given.

Appendix B provides a detailed description of display operation and message formats.

4.1 INSTANTANEOUS VERTICAL SPEED (IVSI) ASA DISPLAY

The IVSI display, shown in Figure 4-2, is the only test display that combines the ASA function with another cockpit display function. It replaces the existing IVSI on both the captain's and first officer's instrument panels (see Chapter Three, Figures 3-3 and 3-4). Vertical speed is displayed in the same manner as on the standard IVSI.

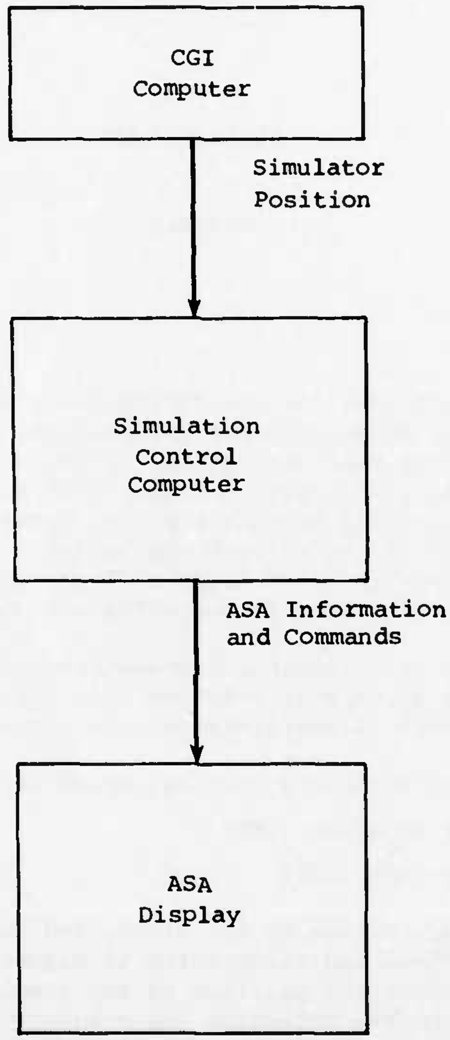

Figure 4-1. DISPLAY DRIVE

Modification of the IVSI to allow presentation of ASA information consists of the following additions:

- No-turn lights
- Limit-climb lights
- Turn-left and turn-right lighted arrows
- Climb and dive lighted arrows

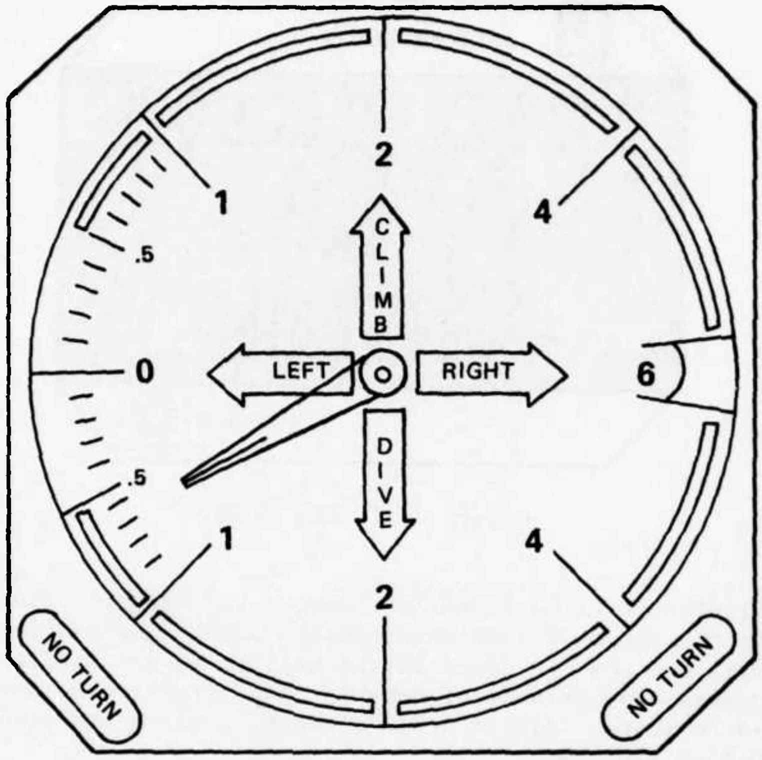

Figure 4-2. IVSI MODIFIED FOR ASA SIMULATION

These added maneuver indicators provide ASA advisories and commands to the pilot. The commands consist of flashing red arrows that instruct the pilot to climb, dive, turn right, or turn left. Two no-turn lights illuminate to remind the pilot to level his wings while performing a vertical avoidance maneuver. These lights are never lighted simultaneously with a turn-right or turn-left command.

Advisory information is provided in the form of yellow lights, which indicate the presence of an aircraft above or below. The yellow lights establish vertical speed restriction, advising the pilot to limit his vertical speed to 500, 1000, 2000, or 4000 feet per minute.

4.2 LIGHT EMITTING DIODE (LED) MATRIX DISPLAY

The LED display used for the ASA simulation, illustrated in Figure 4-3, represents the first application of this technology in an air transport aircraft cockpit. It is a three-color display with ASA advisory and warning messages in alphanumeric characters, augmented by a limited number of symbols. The messages are similar to the ATC shorthand used by many pilots.

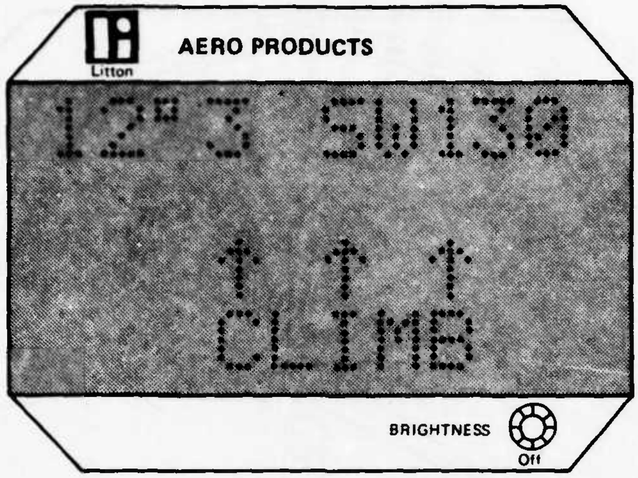

Figure 4-3. LED DISPLAY

Two LED displays will be installed, one on the captain's instrument panel and one on the first officer's instrument panel. Advisories of nearby traffic will be shown in green if the traffic is not conflicting with the present course and altitude of ownship. The traffic advisory shown in Figure 4-3 indicates traffic at 12 o'clock, 3 miles away, southwest bound at 13,000 feet altitude.

Maneuver limitations, such as turn and climb restrictions, are displayed concurrently with traffic advisories; however, these messages will be presented in amber.

Positive maneuver commands will be displayed in red. No other commands or advisories will be displayed when a positive maneuver command is displayed. These commands -- turn right, turn left, climb, and dive -- will be repeated on all lines of the display and will be flashing commands.

This LED display is being developed by the Aero Products Division of Litton Systems, Inc., who have provided it for use in this project. Their interest, advice, and assistance are greatly appreciated.

4.3 CATHODE RAY TUBE (CRT) DISPLAY

Although CRT displays are used in some military aircraft, they have not been generally adopted for commercial transports except as airborne weather displays. The CRT display of ASA information will use symbols for display of traffic advisories and alphanumerics for display of commands. One CRT display will be installed in the flight simulator, replacing the current weather radar display in the center console. The display is illustrated in Figure 4-4.

The positions of other aircraft that pass the ASA logic coarse screen filter are displayed in relation to ownship. Each aircraft is displayed

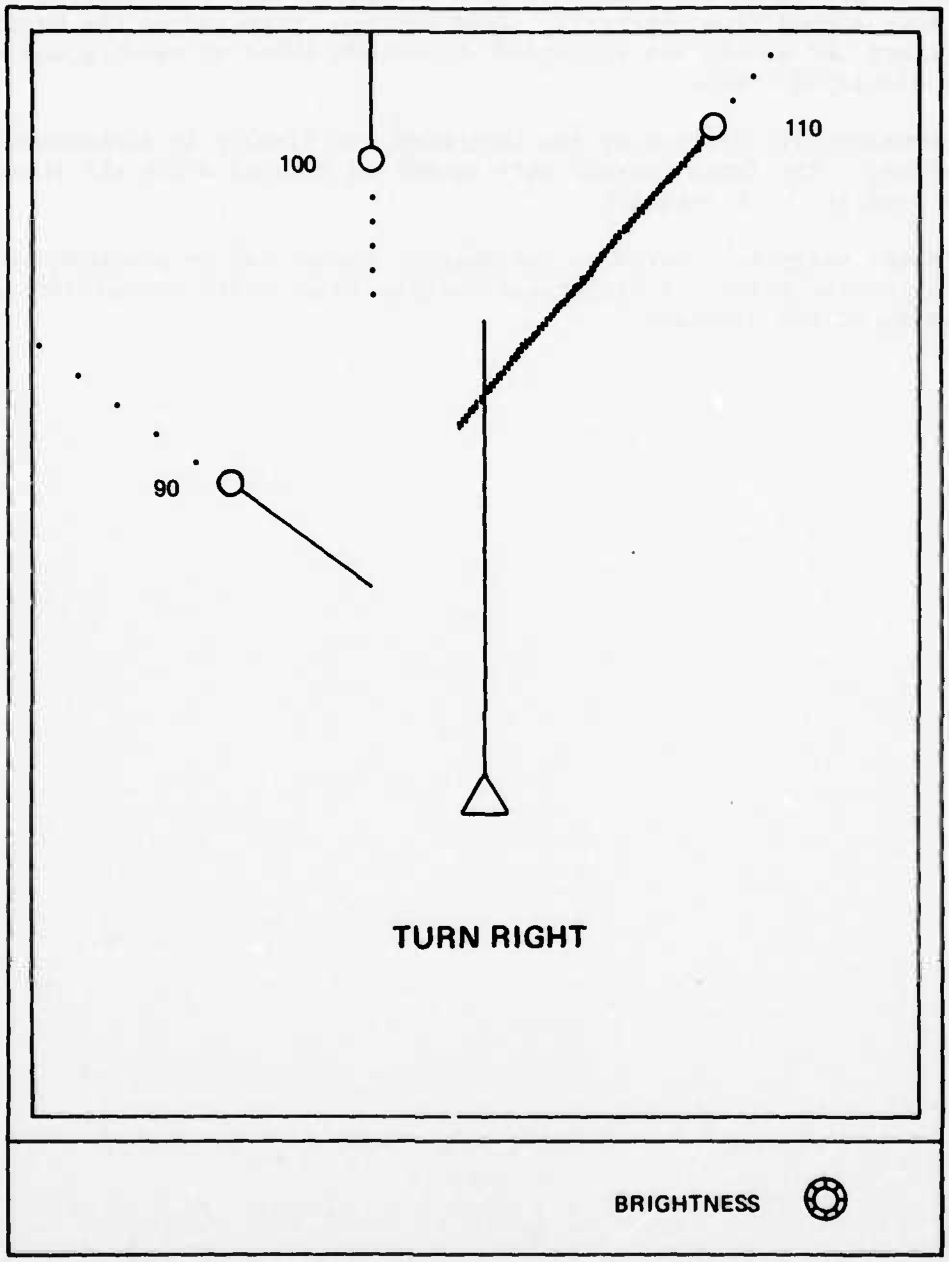

Figure 4-4. CRT DISPLAY

by a symbol with an attached numerical altitude tag. Up to five trail positions are shown for each displayed aircraft, each representing successive four-second time intervals. Lead vectors, computed on the basis of past track and speed, are projected 30 seconds ahead of ownship and all other displayed tracks.

Commands are written at the bottom of the display in alphanumeric characters. The intruding-aircraft symbol is flashed while the intruder is in conflict with ownship.

Range markers centered on the ownship symbol may be presented at the request of the pilot. A brightness control is provided for adjusting the intensity of the display.

CHAPTER FIVE

SIMULATION SOFTWARE

The simulation software consists of six parts:

1. The RSC-11M Executive provides all simulation timing and provides coordination between the other modules.
2. The initialization module provides initial values for the collision avoidance parameters and simulation variables.
3. The simulator interface module performs the transfer of light position and simulator data between the CGI and simulation control computers.
4. The simulation control module performs traffic generation and tracking, exercises the collision avoidance logic, provides monitor graphics, and performs data collection.
5. The display generation logic drives the collision avoidance displays.
6. The interaction module provides interactive simulation control.

5.1 THE RSX-11M EXECUTIVE

The RSX-11M Executive is part of the operating system of the simulation control computer. The executive performs timing and scheduling functions for the simulation. It also provides real-time interrupt response and prioritization of executing modules.

5.2 THE INITIALIZATION MODULE

The initialization module is executed at the beginning of each simulation run. It initializes all of the collision avoidance parameters and simulation variables. Options for a given simulation run are selected and appropriate files are opened. The initialization module exercises the hardware that drives the cockpit displays and also performs diagnostic checks on the interface hardware, which connects the simulation control and CGI computers.

5.3 THE SIMULATOR INTERFACE MODULE

The interface methodology between the simulation control and CGI computers consists of transferring simulator data (x, y, z, $\dot{x}$, $\dot{y}$, $\dot{z}$, pitch, roll, and yaw) from the CGI computer to the simulator control computer and light-position data (x, y, z of aircraft to be represented by lights) from the simulation control to the CGI computer. The module is executed 20 times per second, corresponding to the CGI display update rate, and controls initiation of the simulation control module. The module is written in assembly language, which provides maximum speed at execution.

5.4 SIMULATION CONTROL MODULE

The simulation control module is initiated once per second by the simulator interface module. The program performs traffic generation, tracking, collision avoidance, monitor graphics, and data collection.

5.4.1 Traffic Generation

Traffic generation consists of reading the traffic data file, initializing aircraft, interpreting the aircraft's flight plan, and updating the aircraft's position and velocity.

The traffic data file contains aircraft start time; ID; initial x, y, and z coordinates; heading; speed; and altitude. Each maneuver command consists of initiation time, magnitude of maneuver, and rate of change. The "active" maneuvers are interpreted and produce control variables (heading change, speed change, and altitude change). These control variables act as input to the simulation aerodynamics. The outputs of the simulation aerodynamics are the new position and velocity of the traffic, which are translated into simulator coordinates for transfer to the CGI computer.

5.4.2 Tracking

The simulation uses a simple alpha/beta tracker that takes "perfect" traffic position data as input. The tracked data serve as input to the collision avoidance logic.

5.4.3 Collision Avoidance Logic

Both passive and active BCAS (Beacon Collision Avoidance System*) are modeled in the simulation. The logic consists of both detection and resolution algorithms. The detection logic uses the criteria of range, range rate, tau, miss distance, and altitude separation to determine if two aircraft are in conflict. The resolution logic is capable of producing both horizontal and vertical commands. Negative and limited vertical commands are also available.

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*For conceptual description, see Report No. FAA-RD-77-163, *Initial Collision Avoidance Algorithms for the Beacon-Based Collision Avoidance System*, April 1977.

The collision avoidance logic also sets up the appropriate display parameters and initiates the display generation logic.

5.4.4 Monitor Graphics

A plan view presentation of aircraft positions is displayed on a storage tube graphics terminal to assist in simulation control and to monitor simulation progress. The presentation consists of the air route structure, strategic reference points, and aircraft tracks. Aircraft are represented by characters and are updated on the basis of the tracker update rate.

5.4.5 Data Collection

Data collection will consist of recording time-stamped position and velocity information on all aircraft, maintaining a record of cockpit display status, and recording all parameters associated with the simulation run.

5.5 DISPLAY GENERATION LOGIC

The display generation logic module is initiated by the simulation control logic when a change in any of the cockpit displays is required. The module contains all of the scaling, clipping, drawing, and character-generation routines needed to create an image on the displays. It also includes all of the logic required to drive the display electronics. The module is a background running program; it adjusts its own priority according to the nature of its current function.

5.6 INTERACTION MODULE

The interaction module is initiated from the simulation console and is used to request information about the simulation, initiate new scenarios, modify simulation parameters or options, and maintain control of simulation parameters.

CHAPTER SIX

EXPERIMENTAL PROCEDURE

To compare the different display types under consideration and to meet the objectives stated in Chapter Two, a number of measures will be generated during the tests, including:

- Response times
- Magnitude of response
- Interpretation of commands
- Pilot preference
- Magnitude of deviation from desired flight path
- Recovery times

An ancillary objective is to determine how these measures are affected by various influencing factors, such as:

- Presence of visual representation of intruder
- Display hardware
- Phase of flight
- Background (light, dark) behind intruder

In the design of an experiment to meet the objectives set forth in Chapter Two and elicit the actions that will generate the response measures, two criteria must be considered: (1) interaction between causal factors and (2) variation in measures due to factors not included in the experiment. Crew background is an example of such variation.

The first criterion can be accommodated by obtaining responses while varying all experiment factors simultaneously rather than one at a time. The second criterion can be accommodated by randomizing the factor combinations and using a valid sample size.

6.1 SCENARIO/CREW ASSIGNMENT

Thirty aircrews will be tested during the experiment. Up to 15 of these crews will be paid line-qualified operational crews provided by

United Airlines. Fifteen crews will be volunteer crews from other airlines or pilot groups. Crews will consist of a captain and a first officer. The second officer's duties will be performed by a United Airlines B-727 Flight Operations Instructor (FOI).

Six scenarios, as described in Appendix A, will be employed. Each scenario consists of a flight profile typical of a departure from the Los Angeles International Airport to an assigned cruise altitude and a descent, approach, and landing at the Los Angeles Airport. Each of the six scenarios may be combined with any of the three display types, for a total of 18 distinct combinations.

During each two-hour experimental session, each crew will fly three scenarios, using a different type display for each scenario. A total of 90 flights will be conducted. Each scenario/display combination will be flown by five crews.

The basic experimental unit is one flight. Each crew will fly three flights during its experimental period. Flight scenarios are balanced to provide an even distribution of takeoff and landing directions. Each flight scenario consists of takeoff, climb, cruise, approach, and landing phases. Flight scenario and display assignments by crew are shown in Table 6-1. All factors are randomized. Each of the scenarios is repeated 15 times and each display is flown 30 times. The position of each scenario within the flight position is randomized as to first, second, or third. The order in which the displays are presented to the crews is also evenly distributed.

6.2 SCENARIOS

The scenarios were selected for this experiment to permit evaluation of crew reaction in a realistic flight situation. Each scenario includes all phases of flight: departure, climb, en route, descent, and approach. Six scenarios will be used, with flights departing Los Angeles International Airport using standard Air Traffic Control procedures and, following a mid-course turn-around, receiving clearance back to Los Angeles for an approach and landing. All flight plan information will be presented to the crew before the experiment starts.

Each scenario contains six conflict situations. The initial geometries of the conflicts are shown in Appendix A. Upon initiation of a conflict, the crew will be free to maneuver the simulator as necessary to avoid the otherwise probable collision. The objective of controlling the initial encounter geometry is to allow the same situation to be presented to each crew.

Table 6-1. CREW TEST ASSIGNMENTS			
Crew	Scenario/Display Combination		
	First Flight	Second Flight	Third Flight
1	6-A	2-B	1-C
2	1-B	6-C	5-A
3	1-C	2-A	3-B
4	5-C	3-B	2-A
5	2-B	3-C	4-A
6	2-C	3-A	4-B
7	3-A	1-B	2-C
8	3-B	2-C	5-A
9	3-C	4-A	5-B
10	4-A	5-B	3-C
11	4-B	1-C	6-A
12	4-C	5-A	3-B
13	5-A	6-B	1-C
14	5-B	6-C	1-A
15	5-C	6-A	1-B
16	4-A	6-B	2-C
17	7-B	1-C	2-A
18	6-C	1-A	2-B
19	5-A	2-B	3-C
20	2-A	4-C	6-B
21	3-B	2-A	5-C
22	3-A	1-B	4-C
23	2-B	3-C	4-A
24	2-C	3-A	4-B
25	1-A	4-B	6-C
26	1-B	4-C	3-A
27	6-C	4-A	5-B
28	1-A	5-B	6-C
29	6-B	5-C	1-A
30	4-C	5-A	6-B

Numbers indicate scenario used (see Appendix A).
Letters indicate display used: A = IVSI, B = LED, C = CRT.

The six scenarios used in this experiment are as follows:

	Departures	Approaches
1.	LAX to LAS T/O Runway 25R Daggett Five departure Las Vegas transition Altitude: FL190	Start at MEANT intersection; altitude FL190; route V210 Downey; approach: ILS RWY 25R
2.	LAX to SAN T/O Runway 7L San Diego Six departure Mission Bay transition Altitude: 14,000'	Start at PACIFIC intersection; altitude 14,000' route V23 SLI direct; approach: ILS RWY 24L
3.	LAX to BFL T/O Runway 25R Gorman Four departure Bakersfield transition Altitude: 14,000'	Start at GMN VOR; altitude 14,000'; route V299 FIM, 158°R FIM, STEMS; approach: ILS RWY 7L
4.	LAX to LAS T/O Runway 7L Bouquet Three departure Troy transition Altitude: 16,000'	Start at PMD VOR; altitude 16,000'; route V197; approach: ILS RWY 25L
5.	LAX to SBA T/O Runway 7L Ventura Three departure Santa Barbara transition Altitude: 11,000'	Start at V25/V27 intersection; altitude 11,000'; route V186 FIM, V299; approach: ILS 6R
6.	LAX to SAN T/O Runway 24L Catalina Two departure Altitude: 14,000'	Start at PACIFIC intersection; altitude 14,000'; route V23; approach: ILS RWY 6R

Each of these scenarios describes a flight of about 35 minutes and incorporates a typical departure and typical approach to the Los Angeles International Airport. Six intruders are encountered during each flight. The same encounter geometry is used in all flights; however, the sequence in which they are presented is varied to realistically accommodate the specific flight path. The scenarios are presented in detail in Appendix A. The content of these scenarios should not be divulged to personnel who will participate in the experiment.

6.2.1 Scenario 1: Los Angeles to Las Vegas, ILS Runway 25R Approach

After departure on runway 25R, the flight is vectored westbound over the ocean until it reaches 6,000 feet, when it is turned to the departure track that will intercept V210 to Las Vegas in the vicinity of MEANT intersection. The first conflict is created at the point where the departure track crosses under the inbound vector track that generally overlies V107. The conflict simulates an inbound aircraft that descends below its assigned altitude.

Following resolution of this conflict, the flight is vectored toward MEANT and cleared to climb to its cruising altitude. During the climb, two additional conflicts are presented. When the flight arrives over MEANT, it

is vectored into the profile approach for runway 25R. One conflict is presented during the vector, and two additional conflicts are presented on the final approach. One of these conflicts simulates an overshoot of an aircraft making a parallel approach to 24L.

6.2.2 Scenario 2: Los Angeles to San Diego, ILS Runway 24L Approach

The flight departs runway 7L and climbs to 6,000 feet and is then vectored to intercept V25 at PACIFIC intersection. The first conflict will occur when the simulator starts its turn away from the departure runway heading to cross V16. Two additional conflicts will be generated before it reaches PACIFIC. The simulator will be cleared to intercept V20 inbound to SLI and vectored for an approach to 24L. Conflicts will be generated during the initial approach and final approach segments of the flight, including a parallel approach conflict.

6.2.3 Scenario 3: Los Angeles to Bakersfield, ILS Runway 7L Approach

The flight departs runway 25R and is vectored west, crossing under inbound V107 traffic at 6,000 feet. A conflict will be generated at this crossing point. The flight is then vectored to intercept V23. Two additional conflicts will be generated before it reaches GMN, where it will be vectored to intercept V299 to FIM. One conflict will be generated on this leg. After FIM, the flight will be vectored via MUD intersection for an ILS runway 7L approach. Two conflicts will be generated during this phase, one involving a parallel ILS approach.

6.2.4 Scenario 4: Los Angeles to Las Vegas, ILS Runway 25L Approach

The flight departs runway 7L and after an initial climb is vectored to intercept V165, at which point the first conflict occurs. The flight is subsequently cleared to PMD via V165 and V518 to PMD, with one conflict occurring on each airway. After reaching PMD, the flight is cleared via V197 and V210 to the runway 25L localizer. Two conflicts occur before it reaches the localizer, and one conflict occurs on the parallel ILS approach.

6.2.5 Scenario 5: Los Angeles to Santa Barbara, ILS Runway 6R Approach

The flight departs runway 7L and is vectored south of the airport to intercept V25 at EXERT intersection. One conflict will occur during this phase. After EXERT, the flight will be cleared via V25 at 11,000 feet. One conflict will occur before it passes VTU. After crossing V27, the flight will be vectored to intercept V12S to FIM. One conflict will occur at the initiation of the turn to intercept V12S. After FIM, the flight will be vectored to intercept the localizer for runway 6R. Two conflicts will occur during the vector, and one conflict will occur on final approach.

6.2.6 Scenario 6: Los Angeles to San Diego, ILS Runway 24L Approach

The flight departs runway 24L and is vectored to intercept V25 approximately 6 miles south. One conflict will occur during this segment. The flight climbs to cruise level on V25. Two conflicts occur during this

segment. When over PACIFIC intersection, the flight will be vectored to intercept V23 and will be cleared to SLI. One conflict will occur during this segment. The flight will be vectored to the west of the airport to position it to intercept the runway 6R localizer. One conflict will occur during this segment. An additional conflict will occur during the final approach to runway 6R.

6.3 OPERATING PROCEDURE AND PERSONNEL

In addition to the flight crew, three people will be required to conduct a simulation run: the flight operations instructor/simulator operator, the simulation controller, and the test observer. The functions of each of these personnel during a typical simulation run are described in the following subsections, and their normal positions are shown in Figure 6-1.

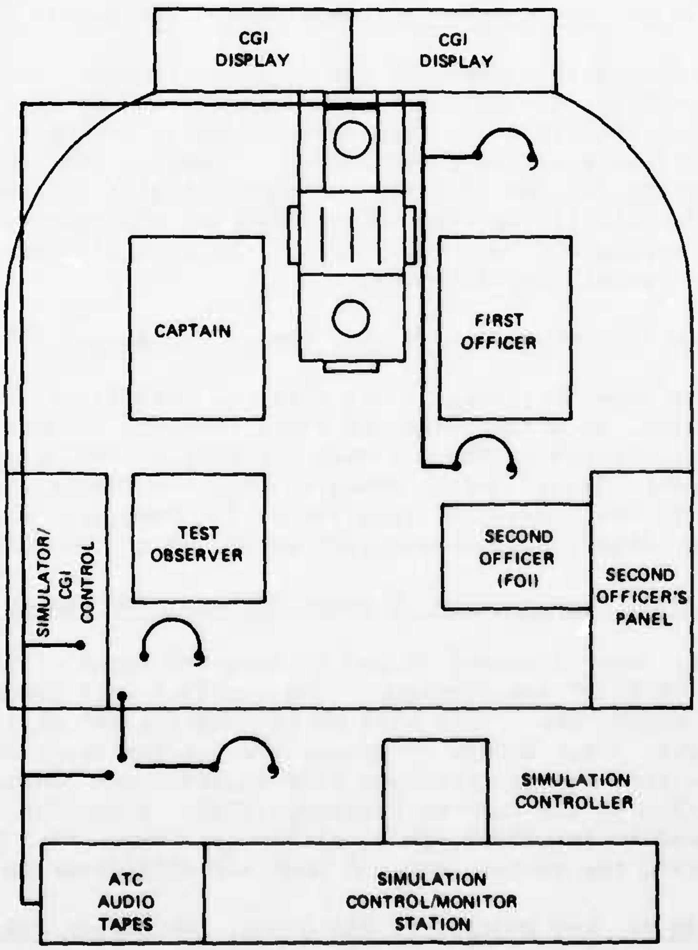

Figure 6-1. LOCATION OF TEST PARTICIPANTS

6.3.1 Flight Operations Instructor/Simulator Operator

The flight operations instructor/simulator operator (FOI) will be an employee of United Airlines. He will perform the normal second officer crew duties and will control the B-727 simulator and associated CGI.

6.3.2 Test Observer

The test observer will be an ARINC Research or United Airlines employee. He will have the following major functions:

- Observe and record crew actions for purposes of data collection
- Advise the simulation controller on initiation of encounters
- Issue necessary ATC instructions
- Act as advisor to the crew as necessary (e.g., answer questions regarding ASA device operation)

The test observer will be seated inside the simulator during the simulation runs. He will note the actions of the crew before, during, and after each encounter. Particular attention will be devoted to recording the crew's efforts to acquire the intruder visually and the exchange of comments between crew members. The test observer will have available two audio channels, one to the simulator communications systems and one to the simulation controller. He will receive requests from the crew and issue clearances via the simulator communications system. He will coordinate the conduct of the simulation run with the simulation controller via a private channel. The test observer ensures that the simulator is in position for the initiation of each encounter.

6.3.3 Simulation Controller

The simulation controller will be an employee of ARINC Research Corporation and will have the following major functions:

- Set the parameters for the scenario that is to be used
- Initiate the encounters at the proper time
- Monitor the progress of the flight and advise the test observer of excessive deviations from the scenario
- Control the automated data recording system

The simulation controller will operate the simulation control computer and associated monitor/control station described in Chapter Three. He will initialize the computer and audio tapes for the scenario to be used and will monitor the flight path of the simulator, comparing it with the programmed path to observe excessive deviations. He will initiate conflicts with other aircraft on the basis of the scenario script or upon request of the test observer. He will monitor the progress of other aircraft (decoys) within the scenario. The simulation controller will monitor and control the operation of the data recording system and the interface between the ASA simulation computer and the CGI computer.

6.4 *CONDUCT OF AN EXPERIMENTAL SESSION*

Before arriving at the simulation test site, the crew will be presented with a packet containing a description of the objectives of the simulation, a description of the displays that will be used in the simulation run, a description of the flight plans, and an ASA system operations instruction and procedures document of the type that would be issued by the airline upon installation of the system in its fleet. An example of these instructions is presented in Appendix B.

Upon arrival at the simulation facility, the crew will be briefed on the three flight plans they will fly and the order in which they will be flown. This selection and sequence will be determined by reference to Table 6-1.

The crew will fly the first flight with the indicated display. At the end of the flight, the display will be covered (or deactivated in the case of the IVSI) and the simulator repositioned for takeoff for the second flight with the second display. At the end of this flight the second display will be covered or deactivated and the simulator repositioned for the third flight of the simulation run. At the conclusion of the third flight the crew will be removed from the simulator and debriefed.

CHAPTER SEVEN

DATA COLLECTION AND ANALYSIS

Data will be collected in three categories -- aircraft position and simulation parameter data, aircraft response and display status data, and pilot opinion data. The aircraft position and simulation parameter data will be used to recreate a simulation run. Aircraft response and display status data will be used to determine pilot reaction time, alarm rates, and command duration.

The pilot opinion data will be combined with the aircraft response and display status data to address the more subjective topics of display effectiveness, command timeliness, etc.

7.1 AIRCRAFT POSITION AND SIMULATOR PARAMETER DATA

Aircraft position (x,y,z) and velocity $(\dot{x},\dot{y},\dot{x})$ data will be stored for each scenario at four-second intervals and for ownship at one-second intervals. Simulator parameter data will be stored once at the beginning of each flight. The data will be time-stamped and will be sufficient to recreate a simulation run. The data can be played back in real or fast time, with the same or different simulation parameters, or with the same or different ASA logic.

7.2 AIRCRAFT RESPONSE AND DISPLAY STATUS DATA

Aircraft response data consists of the simulator motion parameters -- pitch, yaw, and roll. These data will be recorded once per second and will be used to determine when an aircraft begins a maneuver.

The display status data will be dumped whenever the content of the display changes. The data will include the time a command is initiated, the type of command, and time the display is cleared.

The combined data will provide the basis for determining average pilot response time to the various displays used and the amount of time the display is being used to provide collision avoidance information.

7.3 PILOT OPINION DATA

Pilot opinion data will be recorded by means of a questionnaire and debriefing session. The data will include pilot reaction to the scenarios, display and command preference, timeliness of the commands, and usefulness of the CAS information in general. Pilots will be asked to draw comparisons between the displays in terms of symbols used, clarity of presentation, amount of useful data, and work load associated with using the display. Suggestions will be solicited regarding different display techniques, display content, and presentation. Reactions to the experimental test bed will also be recorded.

7.4 ANALYSIS

A statistical analysis will be run on that portion of the data which is statistically significant -- pilot response times, frequency of false alarms (pilots did not feel compelled to respond), miss distances, etc. The pilot opinion data will be summarized in a table illustrating pilot preference and a summary of additional comments.

APPENDIX A

FLIGHT SCENARIOS

This appendix presents the six flight scenarios and conflicts that will be used in the evaluation of ASA cockpit display devices using airline flight simulators.

These scenarios, with their conflict locations, *should* not be shown in advance to any person who will participate in the evaluation as a crew member. To do so might compromise the objectivity of the crew and distort the data.

Each scenario consists of the nominal flight path expected for a flight that originates at the Los Angeles International Airport, follows a standard departure, establishes itself at a cruise altitude, changes course, and returns for an approach and landing at the Los Angeles International Airport (LAX). Prior to the start of the period, the crew will be briefed on the entire flight route, including the point where they will be given clearance to return to the Los Angeles International Airport. The location and types of conflicts will not be given to the crew prior to the start of the experiment. The six flight scenarios are tabulated in Tables A-1 through A-6 and shown graphically in Figures A-1 through A-6. Conflicts are depicted in Figure A-7.

Table A-1. SCENARIO 1: LOS ANGELES TO LAS VEGAS		
Weather: Ceiling measured 5000 overcast, visibility 5 miles, temperature 73, dewpoint 47, wind 270 at 12, altimeter 29, 97.		
Clearance: ATC clears United 104 to the Las Vegas Airport, Daggett 5 departure, Las Vegas transition, maintain flight level 190, squawk 6112, departure runway 25R.		
Sequence Number	Condition	Event
1	Crew calls for takeoff	Clear for takeoff, maintain 6000 departure control 125.2
2	Crossing or abeam LAX VOR	Turn right to 270
3	Reaching 6000	Turn right to 060
4	Acknowledgment of right-turn clearance	Set conflict A
5	Resolution of Conflict A	Clear to FL 190
6	Passing 6000	Increase visibility to unlimited
7	Passing 8000	Contact LAX Center, 126.35
8	2 minutes prior to crossing V-23	Set conflict B
9	2 minutes prior to crossing V-186	Set conflict C
10	Crossing POM R025 (course-reversal point)	Turn right to 180 , maintain FL190
11	30 seconds after rollout on 180	Turn right to 225 , reduce speed to 250, intercept LAX ILS runway 25R, maintain FL190
12	Rollout on 225	Set conflict E
13	Intercept of ILS	Descend and maintain 10,000 LAX altimeter 29.89, APC 124.5
14	Departing 10,000	Set conflict F
15	Contact APC	Cleared for ILS runway 25P approach. Traffic is an American 727 at 8000; two miles ahead for 24L; LAX weather now 300 overcast, 2 miles, light rain, wind 230, 11, altimeter 29.89
16	Passing 8000	Set visibility to 0
17	Passing 8000	Set conflict D

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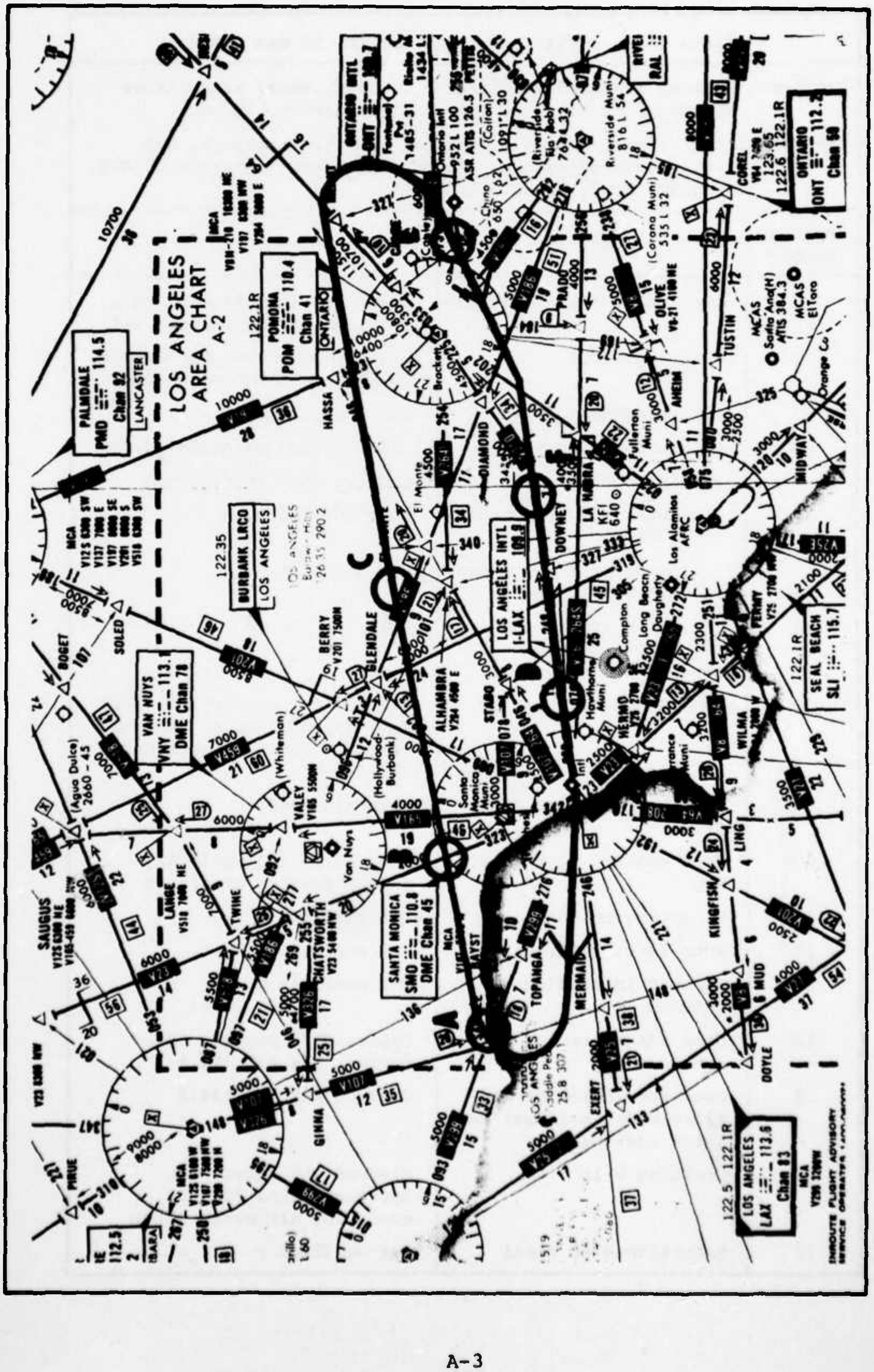

Figure A-1. SCENARIO 1

Table A-2. SCENARIO 2: LOS ANGELES TO SAN DIEGO

Weather: Ceiling measured 4000 broken 6 miles, smog, temperature 62, dewpoint 51, wind 020 at 15, altimeter 30.02.

Clearance: ATC clears United 104 to the San Diego airport, San Diego six departure, flight plan route, maintain 14,000, squawk 6127, departure 7L.

Sequence Number	Condition	Event
1	Crew calls for takeoff	Clear for takeoff, maintain 6000, departure control 124.3
2	Reaching 6000	Right turn to 145 for vector to PACIFIC intersection
3	Acknowledgment	Set conflict A
4	Resolution of conflict	Climb to and maintain 14,000
5	Passing 8000	Contact LAX center 126.0
6	2 minutes prior to crossing V-21	Set conflict B
7	2 minutes prior to crossing SNA R 193	Set conflict C
8	2 minutes after crossing SXC R 062 (course-reversal point)	Turn left to 360
9	Upon acknowledgment of 8	Cleared to LAX Airport, V-23 SLI, direct, descend to and maintain 6000, contact Coast APC 124.2
10	Upon contact with Coast APC	Maintain 6000
10A	Upon contact with Coast APC	Cleared to SLI, hold SE, expect further clearance
11	Departing 10,000	Set conflict F
12	When level at 6000	Set conflict E
12A	Inbound in holding pattern	Set conflict E
12B	Upon resolution of conflict E	Depart SLI, heading 320, contact LAX APC 124.5
13	Upon resolution of conflict E (no holding) and after passing SLI	Contact LAX APC 124.5
14	Crossing V-16	Cleared ILS runway 24L approach. wind 220, 15, gusts 20, altimeter 30.01
15	Established on final	Set conflict D

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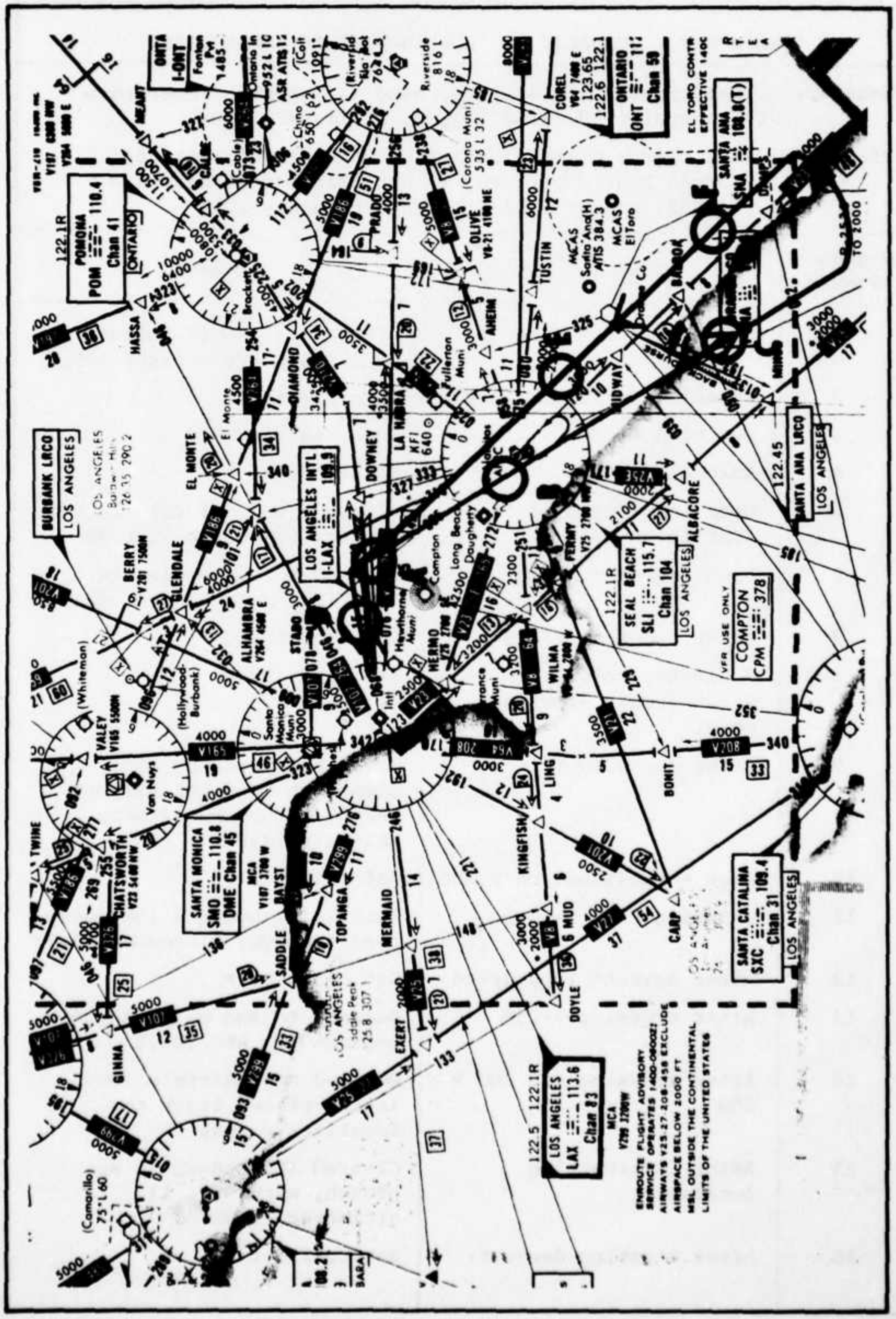

Figure A-2. SCENARIO 2

Table A-3. SCENARIO 3: LOS ANGELES TO BAKERSFIELD		
Weather: Clear, visibility 4 miles, haze and smoke, temperature 63, dewpoint 39, wind 250, 6, altimeter 30.04		
Clearance: ATC clears United 104 to the Bakersfield Airport, Gorman Four departure, flight plan route, maintain 14,000, squawk 6134. Departure runway 25R.		
Sequence Number	**Condition**	**Event**
1	Crew calls for takeoff	Clear for takeoff, maintain 6000 departure control 125.2
2	Crossing or abeam LAX VOR	Turn right to 270
3	Reaching 6000	Turn right to 360
4	Acknowledgment	Set conflict A
5	Upon resolution of conflict A	Climb to and maintain 14,000, contact LAX center 126.35
6	Upon center contact	Cleared to the Bakersfield VOR V 23, maintain 14,000
7	After crossing FIM R 130	Set conflict C
8	2 minutes before crossing V 12S (course-reversal point)	Set conflict B
9	After crossing V 12	Turn left, heading 200, cleared to the LAX Airport V-299, V-107 SMO direct, maintain 14,000
10	When established on V-299	Set conflict E
11	Crossing FIM	Turn left, heading 158, descend to 8000, altimeter 29.98
12	After descent is started	Set conflict F
13	After crossing V-299	Descend to and maintain 5000, contact LAX APC 124.5
14	After crossing the SMO R 259	Descend and maintain 3000, intercept and track the localizer runway 7L
15	After intercepting localizer	Cleared ILS runway 7L approach, wind 080, 11, altimeter 29.98
16	After starting descent	Set conflict D

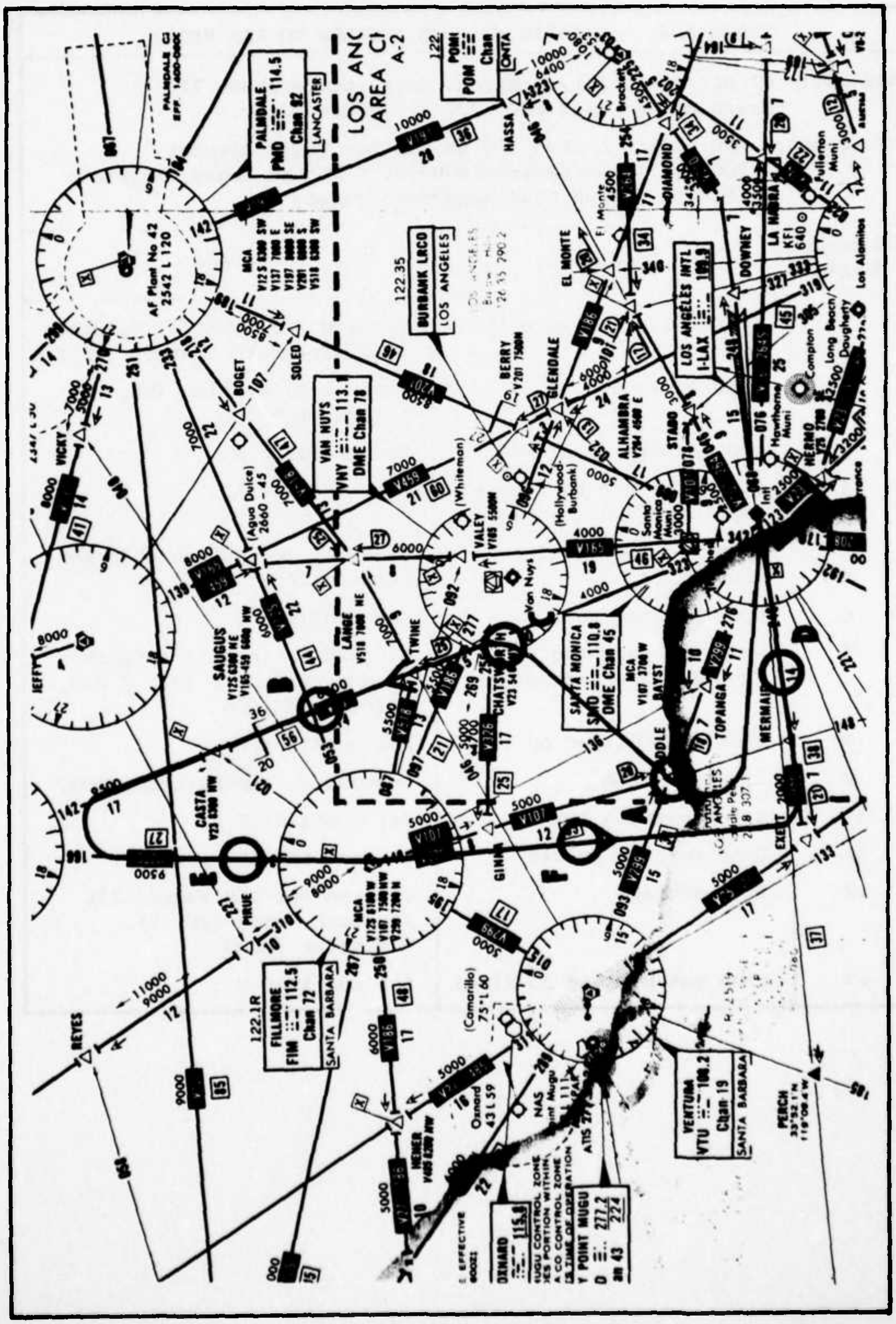

Figure A-3. SCENARIO 3

Table A-4. SCENARIO 4: LOS ANGELES TO LAS VEGAS

Weather: Clear, visibility 5 miles, dust, temperature 72, dewpoint 41, wind 080, 20, altimeter 30.11.

Clearance: ATC clears United 104 to the Las Vegas Airport, Bouquet Three departure V-12, V 8N Las Vegas, maintain 16,000, squawk 6144 departure runway 6L.

Sequence Number	Condition	Event
1	Crew calls for takeoff	Cleared for takeoff, maintain 8000 departure control 125.2
2	Passing 1500	Turn left, heading 300, intercept V 165
3	Upon intercepting V-165	Set conflict B
4	2 minutes before intercept of V 518	Set conflict A
5	Upon resolution of conflict A	Climb to 16,000, contact LAX center 126.35
6	Upon passing 1000	Set conflict C
7	Prior to reaching PMD (course-reversal point)	Cleared to the LAX Airport from over PMD, V 197, V 210, maintain 16,000
8	When established on V 197	Set conflict E
9	Passing HASSA	Descend to and maintain 8000
10	After passing POM	Set conflict F
11	Upon turning to 248	Contact LAX APC 124.5
12	Upon contact	Cleared for ILS runway 25L approach, wind 220, 11, altimeter 30.09
13	When established on final	Set conflict D

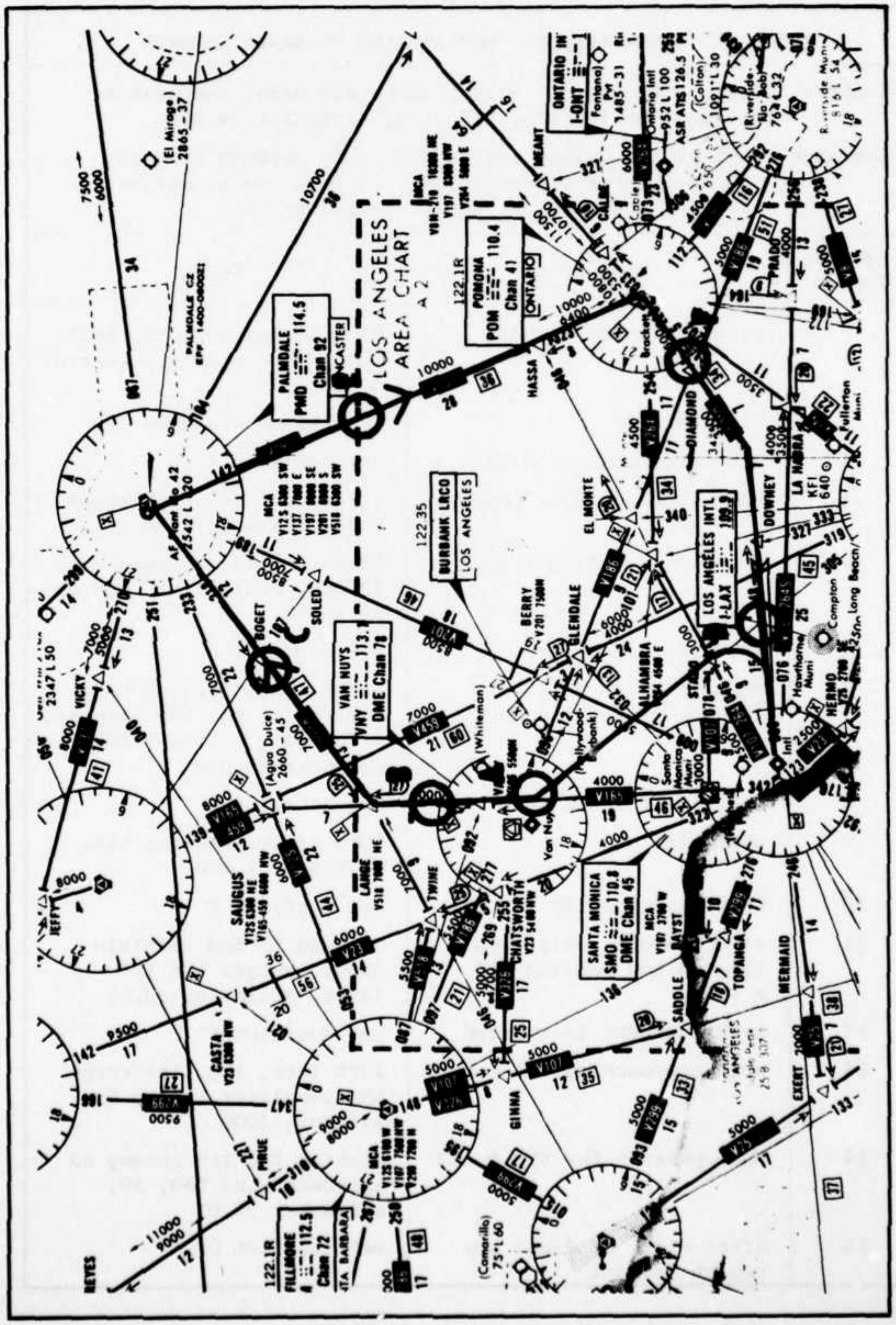

Figure A-4. SCENARIO 4

Table A-5. SCENARIO 5: LOS ANGELES TO SANTA BARBARA

Weather: Clear, visibility 5 miles, smoke and haze, temperature 66, dewpoint 52, wind 060 at 8, altimeter 29.99.

Clearance: ATC clears United 104 to the Santa Barbara Airport, Ventura Three departure, flight plan route, maintain 11,000, squawk 6152, departure runway 7L.

Sequence Number	Condition	Event
1	Crew calls for takeoff	Cleared for takeoff, maintain 4000 departure control 125.2
2	Passing 2000	Turn right, heading 245
3	When established on 245	Set conflict B
4	When conflict B is resolved	Turn right 265, intercept V 27, maintain 6000
5	When intercepting V 27	Climb to and maintain 11,000, contact LAX center on 125.8
6	When starting climb	Set conflict C
7	When 16 miles NW of VTU (course-reversal point)	Right turn, heading 040, cleared to the LAX Airport, V-186 FIM, V-107, V-299, maintain 11,000
8	Starting turn to 040	Set conflict A
9	Over FIM	Turn right, heading 158, maintain 11,000
10	After passing FIM	Set conflict E
11	After resolution of conflict E and passing VTU R 093	Descend to and maintain 3000, contact LAX APC 124.5, altimeter 30.01
12	After descent is started	Set conflict F
13	When approaching ILS course	Turn left, 100, intercept the localizer runway 6R, maintain 3000
14	When passing the VTU R 138	Cleared for ILS runway 6R approach wind 080, 10, altimeter 30.01
15	After start of final approach descent	Set conflict D

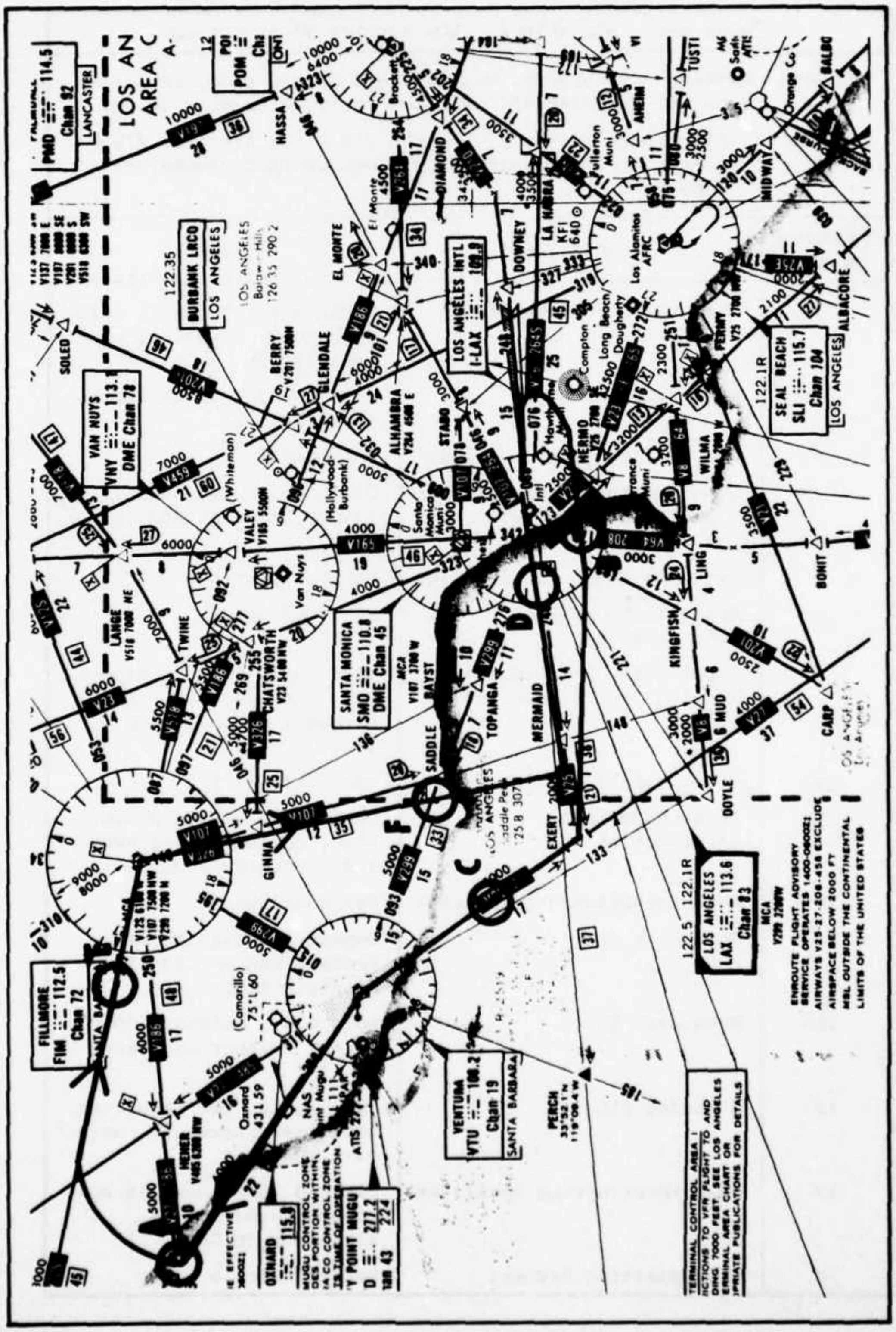

Figure A-5. SCENARIO 5

Table A-6. SCENARIO 6: LOS ANGELES TO SAN DIEGO

Weather: Ceiling 3200 broken, visibility 4 miles, smog, temperature 66, dewpoint 48, wind 090 at 12, altimeter 30.06.

Clearance: ATC clears United 104 to the San Diego Airport, flight plan route, maintain 14,000, squawk 6165, departure runway 7L.

Sequence Number	Condition	Event
1	Crew calls for takeoff	Cleared for takeoff, maintain 4000, departure control 124.3
2	When reaching 4000	Left turn, heading 090 to intercept V25
3	Upon delivery of clearance	Set conflict A
4	Upon resolution of conflict A and approaching V25	Climb to and maintain 14,000, contact LAX center 126.0
5	Crossing WILMA intersection	Set conflict B
6	Approaching MINOE intersection	Set conflict C
7	Approaching PACIFIC intersection (course-reversal point)	Turn left, 360, intercept V23, cleared to the LAX Airport, V23 maintain 14,000
8	After established on V23	Set conflict E
9	Crossing BALBOA intersection	Descend to and maintain 6000, contact Coast APC 124.2 altimeter 30.04
10	When established in descent	Set conflict F
11	When over SLI	Depart SLI heading 270, contact LAX APC 124.5, maintain 6000
11A	When over SLI	Hold S.E., maintain 6000, expect further clearance ___.
12	Crossing V16	Turn right, 060 intercept localizer runway 6R, maintain 6000
13	When intercepting localizer	Cleared ILS runway 6R approach, wind 080, 8, altimeter 30.04
14	When starting descent	Set conflict D

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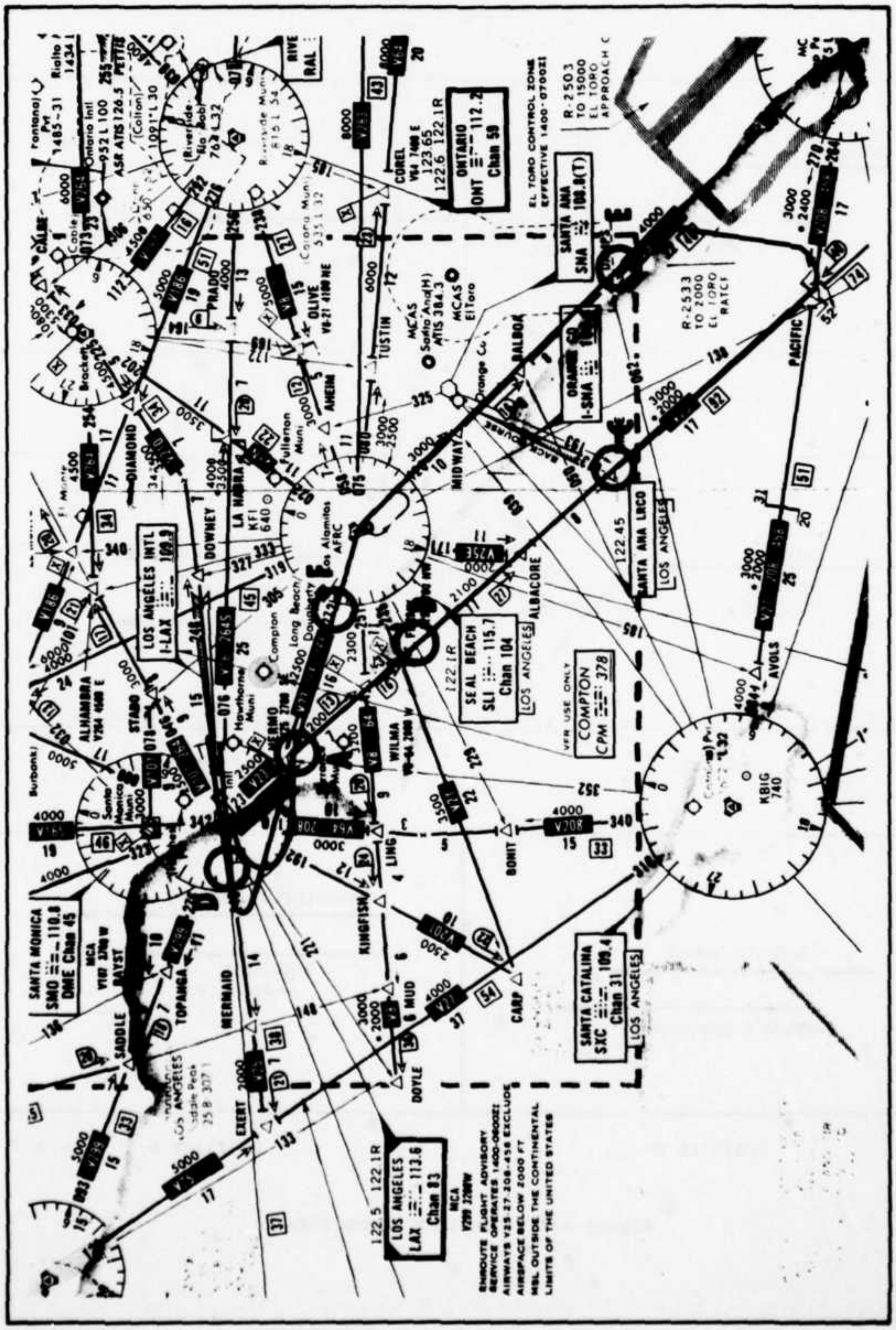


Figure A-6. SCENARIO 6

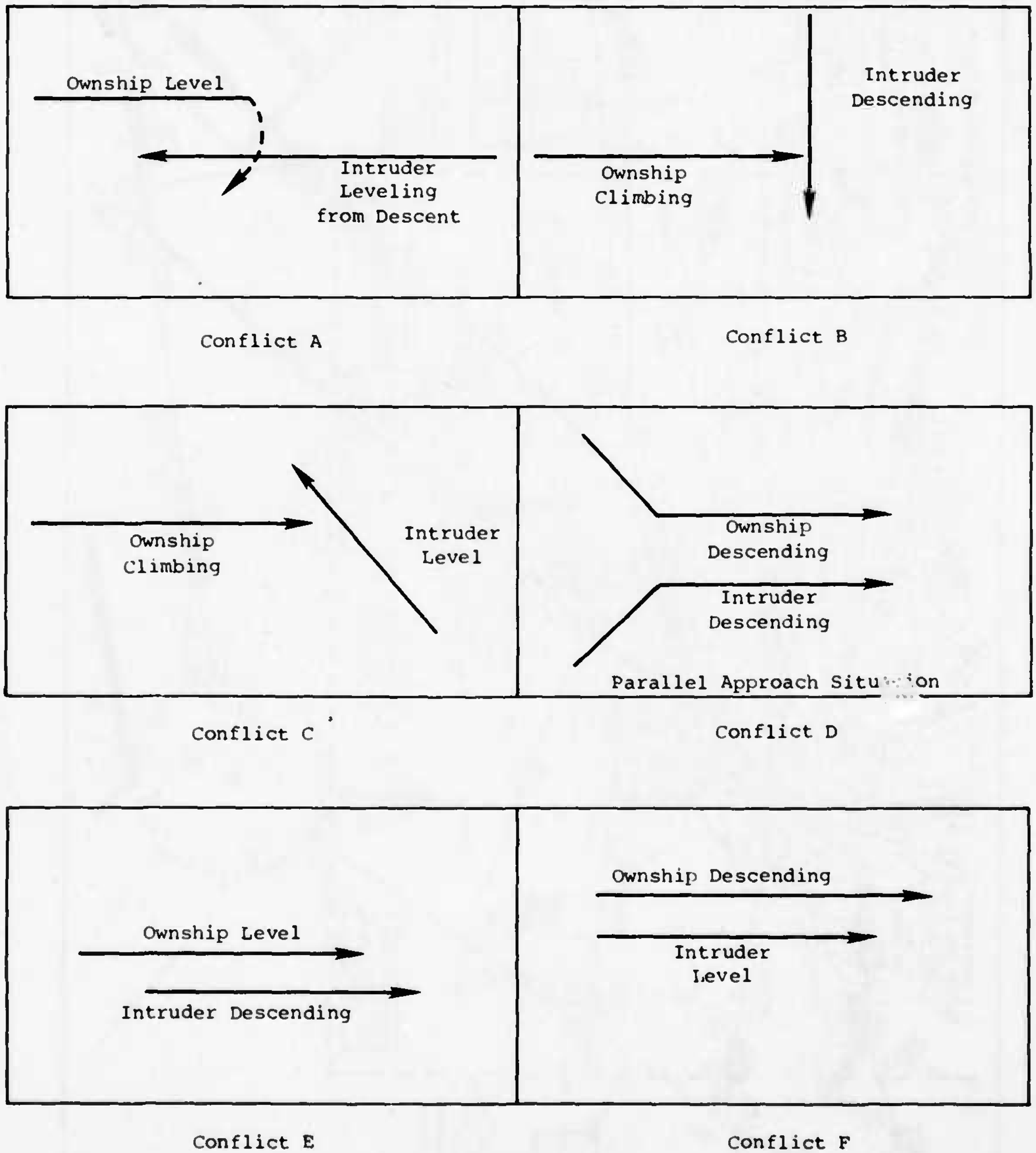


Figure A-7. CONFLICT GEOMETRIES

APPENDIX B

AIRCRAFT SEPARATION ASSURANCE
DISPLAY EVALUATION

This appendix represents a suggested ASA bulletin for the B-727 Flight Manual-Handbook.

B-727 Flight Manual-Handbook
Bulletin #XX
September 1, 1978

1. PURPOSE AND SCOPE

The purpose of the Aircraft Separation Assurance (ASA) display evaluation is to assess airline pilot response to three different display concepts being proposed for a future collision avoidance system. Airline pilot participation has been requested by the FAA and the airlines to gain pilot operational experience and help shape the direction of display development for future cockpit installations.

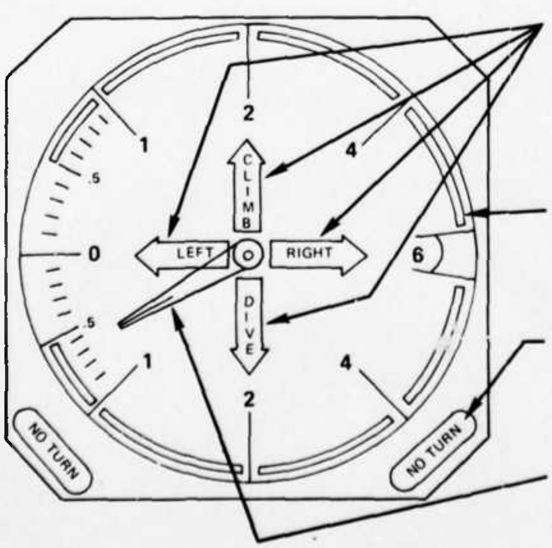
The tests are not intended to evaluate hardware suitable for installation; rather, they will evaluate different conceptual approaches to providing the pilot with traffic advisory warnings and commands for evasive action to prevent an imminent midair collision.

Flight crews will fly a series of three flights, all using different display complements of equipment.

2. DISPLAY FUNCTIONS AND CONTROLS

The three displays being evaluated will consist of a modified Instantaneous Vertical Speed Indicator (IVSI), a Light Emitting Diode (LED) alphanumeric display, and a Cathode Ray Tube (CRT) display, as shown in the accompanying illustrations.

IVSI Indicator



Positive Command Arrows (Climb, Dive, Right, Left)

Indicates computed escape maneuver aircraft should make to avoid collision. Aural warning activated when indicator comes on.

Rate Limit Annunciator

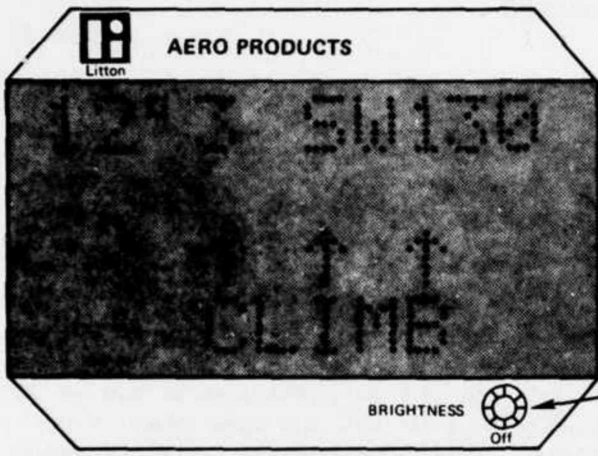
Indicates aircraft climb and descent limits. Vertical speed pointer should not enter lighted segment.

No-Turn Indicator

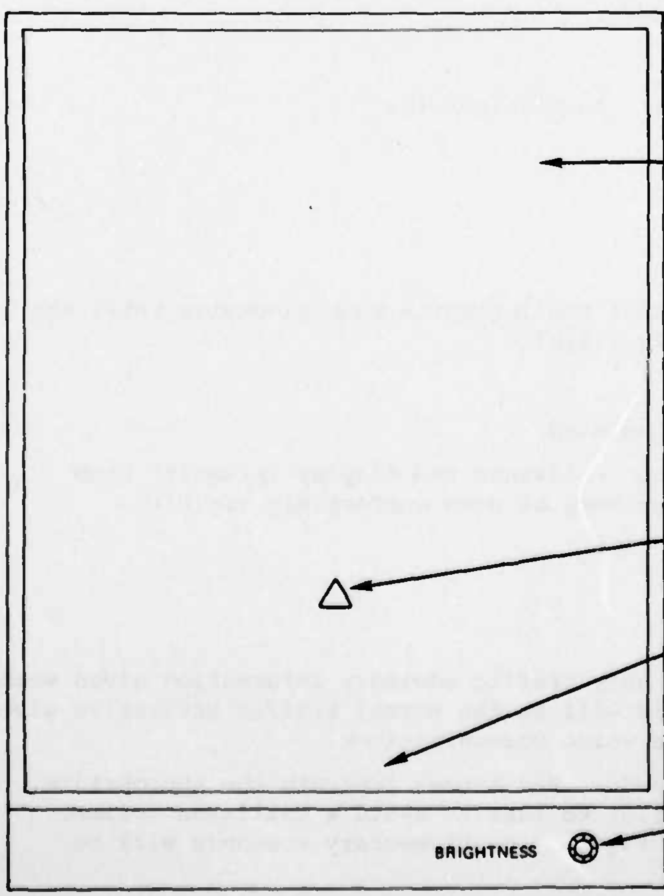
Indicates aircraft should maintain wings level to avoid conflict. Aircraft may otherwise climb or descend.

Vertical Speed Pointer

Shows vertical speed in feet per minute.



LED Display



CRT Display

3. ASA EQUIPMENT OPERATIONAL PROCEDURES

3.1 Criteria for Warnings

Traffic advisories and collision avoidance commands are based on the tracking of transponder replies from surrounding aircraft. The transponder reply times are measured to compute the range to the aircraft. This range is divided by the range rate of change to give the "time to collision", or "Tau".

There are three modes of operation. The en route mode (above 10,000' MSL) utilizes a "time to collision" Tau criterion of 30 seconds to determine when a collision avoidance command should be issued. The transition mode (below 10,000' MSL and over 15 nm from the airport) uses a Tau of 30 seconds. The terminal area mode (below 10,000' MSL and less than 15 nm from airport) uses a Tau of 25 seconds. Switching between modes is automatic and is not detectable by the crew. By reducing the warning time in the terminal area, where aircraft operate at lower speeds and in closer proximity to each other, nuisance and false alarm warnings are reduced.

3.2 Equipment Setup and Testing

1. Warmup (CRT only)

   Intensity Knob -- Full Counterclockwise

2. Testing (Reserved)

3.3 Adjustment

1. LED

   Intensity Knob -- Adjust the intensity knob clockwise until the display is comfortably visible

2. CRT

   1-minute warmup -- completed

   Display Intensity Knob -- Advance the display intensity knob clockwise until the picture becomes comfortably visible.

3.4 Display Interpretation

3.4.1 Modified IVSI

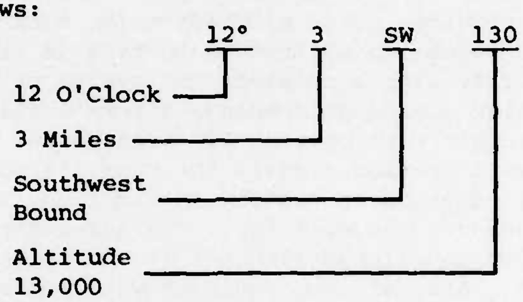
Traffic Advisories: The only traffic advisory information given when this display is being used will be the normal traffic advisories given by the ATC controller via voice communications.

Collision Avoidance Commands: Red Arrows indicate the appropriate evasive action for the pilot to take to avoid a collision (climb, descend, turn left, turn right). Complementary commands will be

given to the other aircraft if it is equipped with suitable equipment. The Rate Limit Annunciator indicates to the pilot that he should not climb or descend in excess of the rate indicated or a traffic conflict could result. An aural warning is activated when a command is given.

3.4.2 LED Display

Traffic Advisories: Traffic advisories will be displayed automatically as detected by the ASA system for properly equipped aircraft. An example follows:

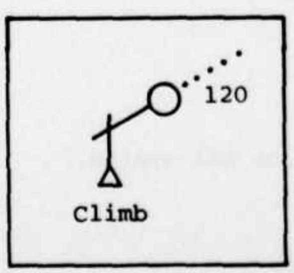


Collision Avoidance Commands: Collision avoidance commands are displayed in the following format (an aural warning is activated when a command is given):

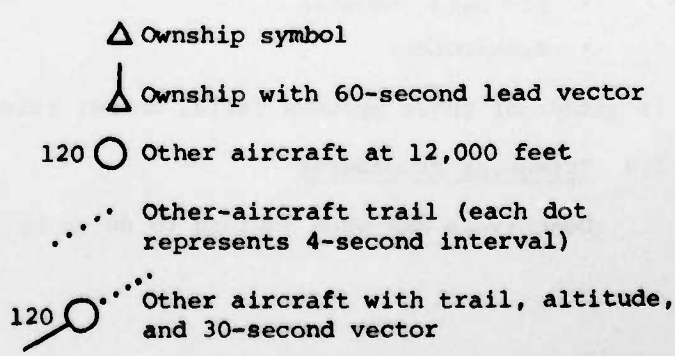
Positive Commands		Negative Commands	
Command	Display Format	Command	Display Format
Turn Left	← Left	No Left Turn	Not Left
Turn Right	Right →	No Right Turn	Not Right
Climb	Climb ↑↑↑	Don't Climb	Dont Climb
Dive	Dive ↓↓↓	Don't Descend	Dont Dive

3.4.3 CRT Display

Traffic Advisories: Traffic Advisories will be displayed in symbolic format automatically as detected by the ASA system:



CRT display showing conflicting traffic at 12,000 feet and ASA command



Note: Display always oriented with aircraft heading up.

Collision Avoidance Commands: Collision avoidance commands are written at the bottom of the CRT display.

3.5 System Limitations

The ASA system requires other aircraft to be equipped with at least an ATC transponder with automatic altitude reporting in order to provide protection. Other aircraft with a complete ASA system on board will receive complementary collision avoidance commands automatically coordinated with your equipment. Aircraft with only an ATC transponder with automatic altitude reporting will provide signals for your aircraft to utilize but will not receive any commands or traffic information, and thus will not know what evasive maneuver you will fly. The ASA-generated maneuvers will avoid a collision with unequipped aircraft if the intruder does not maneuver toward your aircraft. Aircraft not equipped with ASA equipment or a transponder with automatic altitude reporting will not provide the necessary signals for your ASA system to operate.

3.6 Assessment of Possible Evasive Action for Routine Traffic Advisory

When a routine traffic advisory is issued, attain visual contact if in VFR conditions. Utilize available ASA display information to aid in assessing what evasive action might become necessary as the traffic approaches.

3.7 Collision Avoidance Command

In the event of a collision avoidance command, unless VFR with no hazardous condition present, immediately take positive corrective action specified by the ASA System until the warning ceases or aircraft separation is assured.

3.8 Failure Annunciation

ASA system failure can be caused by failure of the following systems that provide information to the ASA display:

- Air Data Computer
- Transponder

If either of these systems fails, do not rely on your ASA system.

3.9 Irregular Procedures

Deactivate ASA when advised to do so by ATC.

APPENDIX C

FLIGHT CREW QUESTIONNAIRE

GENERAL INSTRUCTIONS:

Please complete this list of questions to the best of your ability. Because we value your individual opinion, please do not discuss the simulation period you have just completed until this questionnaire is completed. At that time, the test observer will conduct a discussion period during which you may explore any aspects of the Aircraft Separation Assurance Program you desire.

All your comments, both positive and negative, are welcomed and appreciated.

Thank you for your participation in this program.

FLIGHT CREW QUESTIONNAIRE

Name:____

Company:____

Present Position:____________________ Aircraft:____________

Hours in Type:____

Hours in Transport Aircraft:______________________________

Pilot Certificate(s) Held:______________________________

Total Hours:____

Other (Non-Company) Aircraft Regularly Flown:____________

____

IVSI DISPLAY

1. Is the instrument usable for the IVSI function?

   Yes_____ No_____ Marginal_____

2. Are the "climb" and "dive" commands readable?

   Yes_____ No_____ Marginal_____

3. Are the "left" and "right" commands readable?

   Yes_____ No_____ Marginal_____

4. Are the "no turn" lights readable?

   Yes_____ No_____ Marginal_____

5. Are the limit climb and limit descent segments readable?

   Yes_____ No_____ Marginal_____

6. Are the colors acceptable?

   Red Yes_____ No_____

   Yellow Yes_____ No_____

7. Would you prefer a single color for all command functions?

   Yes_____ No_____

8. If you answer to question 7 was yes, what color would you prefer?

   Red_____ Green_____ White_____ Amber_____

   Orange_____ Blue_____ Other____________________

9. Does the IVSI display provide sufficient ASA information to avoid a collision?

   Always_____ Never_____ Sometimes_____

10. Does the IVSI display cause you to want to make larger than usual pitch changes?

   Yes_____ No_____ Sometimes_____

11. Does the IVSI display cause you to want to make steeper than usual bank angles?

Yes_____ No_____ Sometimes_____

12. With the IVSI display, do you need the audio alert to notify you of an ASA advisory or command?

Yes_____ No_____

13. Would you prefer the command flash instead of the audio alert?

Yes_____ No_____

14. Did the combination of IVSI and ASA functions on one instrument cause distraction from your normal flying tasks?

Yes_____ No_____

15. If so, under what conditions?

Additional comments on IVSI Display. (Continue on reverse side, if needed. Additional paper is available.)

LED DISPLAY

1. Is the display readable?

   Yes_____ No_____ Some Functions Only_____

2. Is the location of the display satisfactory?

   Yes_____ No_____ Marginal_____

3. Is the size of the letters satisfactory?

   Yes_____ Too Small_____ Too Large_____

4. Is the format of the traffic advisories satisfactory?

   Always_____ Never_____ Sometimes_____

5. Were you able to locate traffic on the basis of the displayed information?

   Always_____ Never_____ Sometimes_____

6. Were the traffic advisories as useful as verbal advisories from ATC?

   Always_____ Never_____ Sometimes_____

7. Were the positive commands clear and unambiguous?

   Always_____ Never_____ Sometimes_____

8. Do you need to be alerted to each new traffic advisory?

   Yes_____ No_____ Sometimes_____

9. Do you feel that the LED display distracted your attention from any of the other flight, navigation, or engine instruments?

   Yes_____ No_____

   Explain your answer:

10. Were the colors satisfactory?

Yes____ No____ Some were____

11. Which of these colors do you find objectionable in a cockpit display?

Red____ Green____ White____ Yellow____

Orange____ Blue____ Other________________

12. Do you object to flashing commands on the display?

Yes____ No____

13. Does the LED display cause you to want to make larger than usual pitch changes?

Yes____ No____ Sometimes____

14. Did the LED display cause you to want to make steeper than usual banks?

Yes____ No____ Sometimes____

15. What changes should be made to the traffic advisories format?

16. What are your feelings on the use of alphanumeric messages versus symbolic messages for the ASA system?

Additional comments on LED display. (Continue on reverse side, if needed. Additional paper is available.)

CRT DISPLAY

1. Did you have difficulty seeing the CRT display?

   Always_____ Never_____ Sometimes_____

2. Could you read the commands on the CRT?

   Always_____ Never_____ Sometimes_____

3. Was the range scale used acceptable?

   Yes_____ No_____

   Explain you answer:

4. Was the audio alert useful?

   Yes_____ No_____

5. How do you feel about the target trail?

   Not Needed_____ Too Long_____

   Too Short_____ About Right_____

6. How do you feel about the lead vectors?

   Not Needed_____ Too Long_____

   Too Short_____ About Right_____

7. Was the altitude information useful?

   Yes_____ No_____ Could Not Read It_____

8. Would you prefer target aircraft altitude shown in MSL or altitude relative to ownship?

   MSL_____ Relative_____ Neither_____

9. Were you able to locate traffic based on the displayed information?

   Always_____ Never_____ Sometimes_____

   Explain your answer:

10. Would you like to have the targets tagged with their identification?

Yes_____ No_____

11. What color would you prefer for the display?

Green_____ Yellow_____ Orange_____

Black/White_____ This One is O.K._____

12. Were you able to identify the conflicting aircraft?

Always_____ Never_____ Sometimes_____

13. Did you feel that you wanted to maneuver to avoid possible conflicts even when no command or advisory was present?

Occasionally_____ Often_____ Never_____

14. Would you like the option of selecting heading-up or north-up mode?

Heading-Up Only_____ North-Up Only_____ Both, Selectable_____

15. Did the CRT display give you a confident feeling when maneuvering close to other aircraft with 1,000' vertical separation?

Yes_____ No_____

Explain your feeling:

16. How often did you check the CRT display?

When Flying: Often_____ Seldom_____ Never_____

When Not Flying: Often_____ Seldom_____ Never_____

17. Did checking the CRT display interfere with your other duties?

When Flying: Some_____ A Lot_____ None_____

When Not Flying: Some_____ A Lot_____ None_____

Additional comments on CRT display. (Continue on reverse side, if needed. Additional paper is available.)

GENERAL QUESTIONS

1. Were you familiar with the ASA program prior to your solicitation or selection to participate in this experiment?

   Yes_____ No_____ Vaguely_____

2. Which single display type was most useful?

   IVSI_____ CRT_____ LED_____

3. Do you feel that information on nearby but nonconflicting aircraft is necessary for safe flight?

   Yes_____ No_____

4. Do you feel that traffic advisories may interfere with important cockpit duties?

   Never_____ Often_____ Only in Busy Terminals Areas_____

5. Do you feel that some combination of the displays would be preferable to a single display?

   IVSI/LED_____ CRT/IVSI_____ LED/CRT_____

   IVSI/LED/CRT_____ Prefer One Instrument Only_____

6. Do you think there is a need for some ASA system?

   Yes_____ No_____ En Route Only_____

   Low Altitude Terminal Areas Only_____

7. Did you feel comfortable with the separations you achieved during the simulation?

   Yes_____ No_____ Sometimes_____

8. Do you think an audio alert for commands is needed?

   Yes_____ No_____

   A Better Way Would Be_____

9. Do you regularly fly into LAX?

Yes_____ No_____

10. With the exception of the mid-course turnaround, were the flights relatively realistic?

Yes_____ No_____

11. Were all of the displays usable for the ASA functions?

Yes_____ No_____

11a. If not, which one was not?

LED_____ IVSI_____ CRT_____

12. Rate the displays in order of preference:

First______

Second_____

Third______

Explain the rationale behind your ranking:

Additional comments. (Continue on reverse side, if needed. Additional paper is available.)

DATE
FILMED